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SURVEY REPORT
VOLS. 1–2

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NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT SURVEY REPORT

COMMUNICATION

FROM

THE ASSISTANT SECRETARY OF THE ARMY (CIVIL WORKS)

TRANSMITTING

A CORPS OF ENGINEERS REPORT ON THE NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT, IN PARTIAL RESPONSE TO THE REQUIREMENT FOR A NORTHEASTERN UNITED STATES WATER SUPPLY STUDY ENACTED UNDER TITLE I OF PUBLIC LAW 89-298

IN TWO VOLUMES

VOLUME I

MARCH 19, 1980.—Referred to the Committee on Public Works and Transportation and ordered to be printed

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U.S. GOVERNMENT PRINTING OFFICE

59-652 O WASHINGTON: 1980

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

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LETTER OF TRANSMITTAL

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
WASHINGTON, D.C. 20310

7 MAR 1980

Honorable Thomas P. O'Neill, Jr.
Speaker of the House of Representatives
Washington, D. C. 20515

Dear Mr. Speaker:

I am transmitting herewith a report dated 10 September 1976 from the Chief of Engineers, Department of the Army, together with accompanying papers and illustrations on Northfield Mountain Water Supply Project, in partial response to the Northeastern United States Water Supply Study legislation enacted 27 October 1965, under Title I of Public Law 89-298.

The views of the Commonwealth of Massachusetts; the States of New Hampshire and Vermont; the Departments of the Interior and Transportation; the Federal Power Commission; the Environmental Protection Agency; and the New England River Basins Commission are set forth in the enclosed communications, together with the replies of the Chief of Engineers to the Department of the Interior and the New England River Basins Commission. The environmental statement required by the National Environmental Policy Act of 1969 has been submitted to the Council on Environmental Quality.

The Chief of Engineers has recommended that the single purpose municipal and industrial water supply project be authorized for construction. Although some elements desirable for Federal construction are present (interbasin transfer of water from an interstate stream and a metropolitan service area), I can find no clear-cut advantage for Federal construction at this time. The Commonwealth of Massachusetts has not exhibited strong support for construction. Their latest policy statement on water supply (May, 1978) requires local supply and conservation options to be exhausted and that environmental effects be within acceptable limits before interbasin transfers are made. The New England River Basins Commission also adopted in June 1979 an amendment which revised their 1980 Connecticut River Basin Plan to be consistent

with the Commonwealth policy on interbasin water transfers. The State of Connecticut has also, through statements of Governor Grasso and by Senate Joint Resolution No. 33, 26 April 1979, strongly objected to diversion of Connecticut River Basin waters.

Because of the foregoing I do not concur with the recommendation of the Chief of Engineers. No further Federal action is warranted at this time. However, information in the report should prove useful to local interests and others concerned with river basin and regional planning in the Commonwealth of Massachusetts. This report is therefore provided for information only.

The Office of Management and Budget advises that there is no objection to the submission of the Chief of Engineers report to the Congress. A copy of the letter from the Office of Management and Budget is enclosed as part of the report.

Sincerely,

Michael Blumenfeld
Assistant Secretary of the Army
(Civil Works)

Enclosure

x

COMMENTS OF THE OFFICE OF MANAGEMENT AND BUDGET

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

December 19, 1979

Honorable Clifford Alexander
Secretary of the Army
Washington, D.C. 20310

Dear Mr. Secretary:

Assistant Secretary Michael Blumenfeld's letters of December 3, 1979, submitted the reports of the Chief of Engineers on Northfield Mountain Water Supply Project and Millers River Water Supply Project, for advice as to their relationship to the program of the President pursuant to Executive Order No. 12113, dated January 4, 1979.

Assistant Secretary Blumenfeld proposes to transmit the report to the Congress for information only.

This office would have no objection to the transmission of the reports to the Congress on this basis.

Sincerely,

Curtis A. Hessler
Associate Director

COMMENTS OF THE COMMONWEALTH OF MASSACHUSETTS

THE COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE DEPARTMENT
STATE HOUSE • BOSTON 02133

MICHAEL S. DUKAKIS
GOVERNOR

January 20, 1976

Major General J.W. Morris
Acting Chief of Engineers
Dept. of the Army
Washington, D.C. 20314

Dear General Morris:

Thank you for sending us the engineering reports and the revised draft environmental statement on the Northfield and Millers River Water Supply Projects. These reports along with the memoranda from the Board of Engineers and the recommendations of the Chief of Engineers have been reviewed by the appropriate agencies of the Commonwealth.

First, I wish to express my appreciation for the fine work done by the New England Division of the Corps of Engineers in connection with these two projects and their cooperative attitude towards the Commonwealth's agencies participating in these studies, during the past several years.

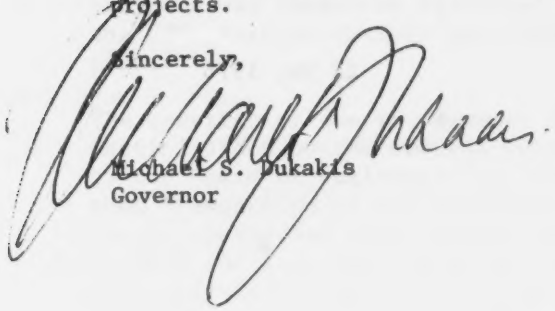
Please be assured of the Commonwealth's continued interest in these projects as expressed in my letter of March 11, 1975. The Commonwealth is embarking on a review of current water supply planning and exploring possible new avenues of policy for the future. While this activity may influence our position on the ultimate implementation of the projects, we continue to support the Corps efforts to obtain additional Congressional authorization and funding for further engineering and design work.

We understand that the proposed reimbursement arrangements will be in accordance with the Water Supply Act of 1958. Upon completion of engineering and design work, I believe the Commonwealth will be prepared to consider the matter of assurances. At that time it will also be appropriate to explore the legal and financial issues regarding expansion of the Metropolitan Water District.

We wish to acknowledge the conclusion of the Chief of Engineers and the Board of Engineers that a formal agreement between the State of Connecticut and the Commonwealth of Massachusetts need not be a prerequisite to further Corps' involvement in the project.

We anticipate that the reports will be well received by Congress and that the Corps will receive the necessary funding to pursue its work on these important projects.

Sincerely,



Michael S. Dukakis
Governor

LETTER TO THE COMMONWEALTH OF MASSACHUSETTS

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

REPLY TO ATTENTION OF:

DAEN-CWP-E

27 May 1976

Mr. Frank Gregg
Chairman, New England River
Basin Commission
55 Court Street
Boston, Massachusetts 02108

Dear Mr. Chairman:

Thank you for your letter of 16 April 1976 in which you presented your comments on the Northfield Mountain and Millers River Basin Water Supply project reports and the revised draft environmental statement.

I appreciate the thorough nature of your Commission's review. I feel, however, that many of the comments on the reports are created by the adoption of certain assumptions in the Southeastern New England (SENE) study which differ from those used in our Northeastern Water Supply (NEWS) study. For example, the demand projections developed by SENE estimate only an eleven million gallons per day (mgd) increase in the Boston Municipal demand for the period 1970-1990. This limited increase shown by SENE is in marked contrast to past trends within the city. In fact, during 1975, Boston used as much water as SENE had estimated for 1980. Use of the SENE estimates, based on Boston's experience, could prove to be a lower limit of future needs. I believe conclusions drawn from these forecast demands regarding project selection and implementation must be somewhat guarded. Both the NEWS and SENE studies recognize the need for wise use of our valuable water resources. In this regard, both investigations made recommendations as to the need for further study into water conservation measures, and I see no great difference in the report findings. In fact, the item pertaining to the recent water usage study prepared for the Metropolitan District Commission (MDC) noted in your letter refers to a study prepared as part of a joint MDC-Corps' effort to determine current usage patterns such that appropriate conservation measures could be directed toward areas of need.

With regard to desalination, I see no conflict with the SENE recommendation for increased research, nor do I see conflict between the local use of Plymouth County ground water and the Millers and Northfield recommendations.

I agree that the implications of inter-basin transfer of water from the Merrimack Basin will have to be carefully considered in future planning for meeting the long-term water needs of the Metropolitan Area.

As you note, the SENE recommendations are qualified in that they are predicated upon certain conditions discussed in the 1980 Basin Plan. The plan formulation for both the Northfield Mountain and Millers River projects was conducted with full knowledge of the 1980 Basin Plan and the NEWS recommendations were made in keeping with these earlier developed plans.

The question of the requirement for a regional mechanism prior to participation by the Federal Government in the projects was discussed by the Board of Engineers for Rivers and Harbors. The Board was convinced that "resolution of any jurisdictional claim associated with the project can be approached best through the mechanism of requiring local assurances to hold and save the United States free from water rights claims rather than stipulating specific actions on the involved jurisdictions and thereby infringing upon their sovereign prerogatives." Although I understand your concern, I feel the Board's approach is the best practicable solution from the Federal Government's perspective.

Your comment on the discussions within the revised draft environmental statement is well taken. As you know from your experience in the SENE, the Connecticut Supplemental Study, and elsewhere, impact assessment in many ways is a subjective procedure and one in which exact quantification is not always possible. I believe the data available does allow a decision on the impacts of the project.

In conclusion, I again thank you for your review and comments. Copies of your letter and this reply will accompany the report of the Chief of Engineers on the Northfield Mountain and Millers River projects when they are submitted to the Congress.

Sincerely,

W. C. GRIBBLE, JR.
Lieutenant General, USA
Chief of Engineers

State of Vermont

AGENCY OF ENVIRONMENTAL CONSERVATION

Department of Fish and Game
Department of Forests, Parks, and Recreation
Department of Water Resources
Environmental Board
Division of Environmental Engineering
Division of Environmental Protection
Natural Resources Conservation Council

Montpelier, Vermont 05602

DEPARTMENT OF WATER RESOURCES

January 7, 1976

Mr. Ted E. Bishop
LTC, Corps of Engineers
Assistant Director of Civil Works, Atlantic
Department of the Army
Office of the Chief of Engineers
Washington, D.C. 20314

Dear Colonel Bishop:

In reference to the two proposed reports of the Chief of Engineers on Northfield Mountain and Millers River Water Supply Projects, Massachusetts, the State of Vermont does not desire to comment.

Sincerely yours,

Gordon R. Pyper

GORDON R. PYPER, P.E.
Commissioner

GRP:JEC:j

COMMENTS OF THE STATE OF NEW HAMPSHIRE

State of New Hampshire

WATER RESOURCES BOARD

37 Pleasant St.
CONCORD 03301

ATT: DAEN-CWP

December 23, 1975

Mr. Ted E. Bishop
Assistant Director of Civil Works, Atlantic
U.S. Army Corps of Engineers
Washington, D. C. 20314

Dear Sir:

In reference to your correspondence of December 18, 1975 relative to the Northfield Mountain and Millers River Water Supply Projects, this office did transfer a copy of the report to the Fish and Game Department.

We have not reviewed the project since it does not involve any interests within our jurisdiction in the State of New Hampshire.

Very truly yours,

George McGee Sr.

George M. McGee, Sr.
Chairman

gmcg/vk/c

59-652 O - 80 - Vol.1 - 2

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

ER 75/754

29 October 1975

Dear General Morris:

Thank you for the letters of July 29, 1975, requesting our views and comments on the draft environmental statement and study reports for the Northfield Mountain Water Supply Project, and Millers River Basin Water Supply Project, Franklin, Middlesex, and Worcester Counties, Massachusetts. This letter will address both projects because of the combined environmental statement. We have both general and specific comments arranged by page or section designation:

MILLERS RIVER BASIN WATER SUPPLY PROJECT

The only mineral deposits mentioned under paragraph B, Geology Soil and Mineral Resources, page 14, are sand and gravel. Our records indicate that peat and miscellaneous deposits mined for crushed stone also exist in the area of the project. The project's proponents should indicate precisely where and what minerals occur and their relationship to the project. If any of these minerals are located in the project right-of-way, the project proponents should so indicate and give some estimate of the extent to which future recovery of these minerals will be affected. A map locating the known mineral resources in relation to the project vicinity would allow easier assessment. Any minerals preempted by the project should be described in the section Irreversible and Irretrievable Commitment of Resources.

The Millers River Basin fish habitat resources have not been adequately described on Pages 14-15. As noted in our review of this project's draft environmental statement, the anadromous fish restoration potential in the Millers River Basin should be noted. The impact of diversion on this and improved resident fisheries resources should also be recognized and evaluated.

A description of the environmental setting and natural resources of Quabbin Reservoir should be included in Section 6 of the main report. This will provide some basis for evaluation of the impact analysis of diversions from the Millers River Basin on Quabbin Reservoir.

Control flows for the Millers River Basin diversions are presented as finite on Pages 61 and 66. The Department's Fish and Wildlife Service understood that they were set at "best estimates" for planning. This aspect on control flows should be clarified in the main report. It should be noted that leeway exists for adjustments as environmental considerations warrant.

Page 139, Paragraph 1, line 7. The word "sediments" should be changed to read "segments."

Pages 144-145. The adverse fish and wildlife habitat impacts from pool fluctuations and erosion at diversion sites in the Tully complex are not addressed. This section should discuss the loss of vegetation, silting of streams, restrictions to fish movements, turbidity and other direct or secondary impacts caused by pool fluctuations.

The "Summary Conclusion" section of the main report should include recognition of the need for further studies presented in Appendices I and J. We recommend that the necessity for further studies be recognized in the main report.

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

Page xviii, Paragraph 2. The project report states, "Upon analysis of available data, it was concluded that no water treatment is necessary prior to the diversion of Connecticut River water to Quabbin Reservoir. This conclusion is based on the assumption that proper water quality monitoring of Connecticut River water would be performed in the interim years during construction as well as well as during actual diversion periods and that planned pollution abatement plants will be constructed and in operation." . . . "If pollution loads upstream from the Northfield intake continue unchecked, however, there is no assurance that the quality will remain satisfactory." Further, on Page 56, it is pointed out that ". . . no one knows with certainty what the reservoir's 'treatment plant' capacity is."

If fiscal and/or temporal constraints combine to delay the timely implementation of PL 92-500 (The Water Quality Act of 1972), water-quality conditions may require that Connecticut River water be treated prior to diversion to Quabbin Reservoir. Page 57 of the revised draft environmental impact statement notes, however, that the Metropolitan District Commission plans to chlorinate diverted waters prior to their entry into the Quabbin Reservoir.

Page xiv. "Studies should be conducted to determine whether certain measures designed to conserve and moderate water demand should be implemented to reduce the size of needed long-range water supply developments."

It appears that conclusive evidence already exists to verify the need for measures to conserve and moderate water demand. Although completion of metering would affect only 4 percent of service connections and would be of minor significance, it is nevertheless a component of the problem which should be corrected. Pricing adjustments, restrictions on water use, and public water conservation programs may be unpopular or considered socially unacceptable. We submit, however, that the severity of the problem no longer allows the luxury of implementing only those measures considered socially acceptable. We also submit that metering, pricing adjustments, water conservation, and demand moderation cannot be considered as alternatives; they simply cannot meet the needs. However, they can become workable adjuncts to whatever major method is adopted to supply additional water. In summary, the effect of any single conservation or demand moderation measure may indeed be insignificant, but the combination of several measures could have a sizable impact on the total water supply.

Sand and gravel, and stone are produced in Franklin County, however, the proposed project should have no significant impact on the availability of these resources. In addition, small irregular bodies of pegmatite are found in all pre-Triassic rocks in the area. These pegmatite deposits are potential sources of beryl, feldspar, mica, talc, and quartz. However, all the pegmatites in the project vicinity appear to be small and fine grained. A more favorable area for mining of the feldspar and other associated minerals would probably be in the pegmatite region north of the project where the pegmatites are larger, coarser grained, and more accessible. Another large pegmatite district is located southwest of the project where mining has occurred in the past. We have no indication of mining activity or resources with mining potential in the project vicinity.

Page 14 of the Main Report for Northfield Mountain Water Supply Project, under paragraph B, Geology - Soil - Mineral Resources, paragraph 2, states that "Known occurrences of minerals are numerous. Most of these minerals are located in areas that are not conducive for exploitation under present economic technical conditions." It further notes that there are important

exceptions, namely beryl, mica, gems, abrasives, feldspar, copper, and dimension stone. This paragraph is misleading in that the preceding paragraph, of the report, speaks of the northeastern mountains and the New England upland sections.

The "Recommendations" section (Pages 182-184) of the main report fails to include recommendations for further environmental impact studies listed in Appendix E, Page 121 of Volume III. We recommend these studies be listed in the main report.

The main report discusses in considerable detail the probable effects of water diversion on the donor and receiver water systems. The report, however, does not address the expected cumulation of synergistic environmental effects of existing and planned power production, flood management, irrigation, industrial cooling, and domestic water supply plans as they relate to water diversions. We recommend the report include a consideration of the cumulative effects of water use on the donor riverine system.

DRAFT ENVIRONMENTAL STATEMENT

In our comments of December 20, 1972, regarding the preliminary draft environmental statement, we suggested that a section describing the geology of the region be included in Section II, Environmental Setting Without the Project. We further suggested that a discussion concerning environmental impacts caused by construction be included in Section III, Environmental Impact of the Proposed Action. We appreciate the fact that at least a brief description of the geology has been included in the revised statement. However, the discussion of environmental impacts caused by construction that describes the impacts on public health, ecology, water quality, aquatic life, etc., makes no mention, here or anywhere else in the statement, of the impacts or adverse effects on the existing or potential recovery of mineral resources in the project area.

We believe that mineral resources are important and that an attempt to describe the effects of project construction should be included in the revised statement. If this cannot be accomplished at this time, a statement to this effect should be included in the revised environmental statement.

The environmental statement should discuss the possible effects of earthquakes since the project area is within Seismic Zone 2, where moderate damage can be expected. Earthquakes of intensity V to VIII or IX have been recorded near the eastern edge of the project area.

Although many aspects of the human environment have been considered in the impact analysis of these proposed projects, there is no discussion or adequate concern given to the protection of cultural resources. Previous comments, December 26, 1972, by the Department's National Park Service, on the preliminary draft environmental statements advised the Corps to consult with the State Historic Preservation Officer for Massachusetts to be sure that the proposed undertaking would not affect any historical properties on or being considered for nomination to the National Register of Historic Places. The Corps' response to this is found on p. 151, which we feel is insufficient. If the Corps is to devote much discussion to so many other aspects of the human environment, certainly there is reason to discuss within the impact evaluation text the aspects of cultural resource protection, including archeological values. By the fact the Corps is required to comply with 800 CFR 36 for cultural resource protection and that a commentary from the State Historic Preservation Officer is directly related to this, such a commentary should be displayed in the Appendices and discussed in appropriate places in the text.

By oversight in our December 26, 1972 comments, we failed to draw attention to archeological values to be affected by these projects. By their magnitude certainly there will be archeological values to be affected and only qualified archeologists intimately knowledgeable of the project area can evaluate such potential. It would behoove the Corps, in order to avoid planning design and construction project upsets later on, to consult with such qualified people as Dr. Maurice Robins, Bronson University, 8 North Main Street, Attleboro, Massachusetts 02703 or Dr. Dena F. Dincauze, Department of Anthropology, University of Massachusetts, Amherst, Massachusetts 01002, now and get early advice and follow accordingly. As well as with the State Historic Preservation Officer, the commentaries of archeologists should be displayed and discussed in the environmental statement.

The inadequacies we have noted in the draft environmental statement could be rectified in the final statement.

Page 37, Line 7. Millers River Basin diversion, Alternative 2, is described as a "combination of Alternatives one and three." This is inaccurate and misleading. It would be more accurately described as combining Alternative one with an element of Alternative three (i.e., the East Branch Tully River diversion).

Pages 40-43. The biological resources of the Millers River Basin are not adequately described. Although Atlantic salmon restoration is not presently being contemplated for this watershed, a potential for this resource exists. Construction of fish passage facilities at current impassable dams, plus pollution abatement, would make this watershed's Atlantic salmon spawning and nursery habitat usable. This potential resource and the impact that Millers River Basin diversions would have upon it should be recognized in appropriate sections of the final environmental statement for this project.

While this section notes the impact of diversion of existing resident fishery resources in the Millers River Basin, it does not consider the impact this proposal would have upon these improved fishery resources following pollution abatement.

Page 40, Paragraph 3. The last sentence states, "Recreational use consists of regulated boating . . . ." This should be corrected to show that pleasure boating, as such, is not permitted on Quabbin waters. Boat fishing is permitted, as described on page 60, Volume 1, Special Rules and Regulations. A valid fishing license is required for each

person embarking from the boat-launch areas operated by the Metropolitan District Commission (MDC). Also on Page 60, Volume 1, it is noted that "shore fishing is permitted on the reservoir from three locations." This should be corrected to show that forty-seven miles of shoreline are open to licensed fishermen.

Page 57, Paragraph 2. It is noted that the MDC plans to chlorinate diverted waters prior to their entry into Quabbin. It is further stated, ". . . varying turbidities of these waters and the resultant inefficiencies of chlorination will ensure the possibility that pathogens imbedded within suspended debris could find their way into Quabbin." These statements, and others elsewhere in the draft environmental impact statement, reflect the considerable concern for Quabbin's water quality if diversions are made from the Connecticut and/or Millers Rivers. The following addresses this aspect of the project proposal:

Viable alternatives to chlorination should be examined. One of the more promising is ozonation. Ozone is an extremely strong oxidant and disinfectant that can be used to control color, odor, taste, manganese, iron, and dissolved organics including potentially toxic compounds such as pesticides and detergents. 1/ It also is effective against compounds formed by the decomposition of algae, and it produces no sludges. Ozone has been shown to be a better disinfectant than chlorine, especially for viruses, and its disinfectant properties are not reduced by that of organic compounds. It can reduce turbidity by coagulation, lowers Biological Oxygen Demand, and is relatively short-lived. One precaution in using ozone is that all traces of it must be removed from the treated water (by aeration, insolation, or other means) before introducing it into a natural environment, since even minute concentrations of ozone are highly toxic to aquatic biota.

1/ Generation and Application of Ozone in Water Treatment Facilities. Harvey M. Rosen. June 1974. Journal of the New England Water Works Association.

Further advantages reported for the general use of ozonation over chlorination include:

1. Lower potential for accidents related to use of chlorine; and

2. Availability is not dependent upon market conditions.

A major stated objection to ozonation is its cost. However, if the cost of ozonation is compared to the cost of chlorination, plus dechlorination, plus removal of chlorinated hydrocarbons, plus the possible need for aeration, the benefit/cost ratio is highly in favor of ozonation.

We suggest use of the words "probable" and "possible" be standardized in the titles of Tables 7 and 8 (Pages 60 and 68), and that the specific diversion name be made part of the title; e.g., "Table 7. Summary of Probable Impacts . . . by the Northfield Mountain Diversion Project."

Table 7, Block 4, under Description of Impact, lists a high probability for the introduction of undesirable species into Quabbin from the Northfield Mountain Diversion. On Page 55, however, it is mentioned that it is unlikely that undesirable algal species will be introducted. We recommend that the table be modified, therefore, to show that fish species were intended to be designated in Block 4.

Page 64. Although the proposed project is to function as a flood skimming device the draft statement indicates that diversions "may shorten the (canoeing) season during lower flow periods in the late spring." Further discussion of this point should be made to clarify the project operation and resulting impacts.

We are concerned about the impact of water diversions on existing and potential recreation values, especially impacts which may occur during the major recreation use season. There are existing high quality canoeing reaches on the Millers River. Other stream reaches currently less attractive for this purpose will become more valuable as a recreation resource as water quality improves. The proposed diversion dam will be a physical barrier to passage on the river and will effect flows in the river.

The statement should discuss measures that will be taken to minimize adverse impacts on the use of the river for recreation purposes.

Page 69. It is noted that impact statements will be prepared for the Design and Construction phase and for the Operation and Maintenance stages. We reserve judgment therefore, on those aspects of project proposals for which detailed data are not available now.

Page 94, Paragraph 5. Adverse fish and wildlife habitat impacts resulting from pool fluctuations and erosion at diversion sites on East Branch Tully River and Priest Brook are not addressed. It should be noted that extreme fluctuations during the growing season would adversely affect both terrestrial and aquatic vegetation and, subsequently, the fish and wildlife utilizing these plants for nesting, escape cover, and/or food.

Page 113. The Northfield and Millers River diversions are presented as viable companion projects which would meet both immediate and intermediate water supply needs for the service area. Diversions from the Merrimack and other sources would extend this supply. However, the order in which these diversions would be implemented is not clear. This order should be clarified and if these diversions are to be instituted in a stepwise progression, the need for each project should be reviewed prior to implementation.

If the authorized Northfield Mountain project is implemented first, this could allow time for the construction of treatment facilities in the Millers River Basin. Construction and operation of these facilities prior to diversion will maximize ecological benefits of pollution abatement. The full force of predivision flood flows are likely to provide greater flushing power than those remaining after diversion. This would, in turn, provide greater stream habitat renewal opportunities.

Page 134. It is stated, "No known Endangered Species of birds or animals listed by the Fish and Wildlife Service utilize the proposed project lands." We recommend this be revised. The shortnose sturgeon (Acipenser brevirostrum) has been collected from the Connecticut River in the vicinity of Montague within

recent years. Also, the Quabbin Reservoir land area contains a site listed by the Peregrine Falcon Recovery Team as a potential location for future reintroduction of the American peregrine falcon (Falco peregrinus anatum). Both of these are on the "Endangered Species" List. We recommend the planners consult with the Peregrine Falcon Recovery Team during the planning processes.

The Department's Fish and Wildlife Service is presently reviewing the status of the bald eagle and is considering the potential for including those bald eagles which frequent New England on the "Endangered Species" List. The Southern bald eagle (Haliaceetus leucocephalus leucocephalus), south of the 40th parallel, currently is listed. It is known that representatives of this sub-species migrate into New England during the non-breeding season; hence the present status review and potential for extension of the listing to include birds in the project area.

It should also be noted that future environmental impact statements should include a discussion of endangered plant species affected by project implementation.

As presented, diversions from different river systems would provide significant additional water supplies to the Metropolitan District Commission service area. While tapping one area to provide a resource required by another may solve the immediate problem, the ecological ramifications are likely to increase as additional supplies are needed. The Department wishes to emphasize the need to study further means of lowering existing trends in water demand.

We hope these comments will be of assistance to you in preparing your final documents.

Sincerely yours,

Stanley D. Doremus

Deputy Assistant Secretary of the Interior

J. W. Morris
Major General, USA
Acting Chief of Engineers
Department of the Army
Washington, D. C. 20314

LETTER TO THE DEPARTMENT OF THE INTERIOR

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

REPLY TO
ATTENTION OF:

DAEN-CWP-E

5 March 1976

Mr. Stanley D. Doremus
Deputy Assistant Secretary for
Program Development and Budget
Department of the Interior
Washington, D.C. 20240

Dear Mr. Doremus:

I am writing in response to your letter of 29 October 1975 in which you present your comments on the Northfield Mountain and Millers River Basin Water Supply Project reports and the revised draft environmental impact statements. I appreciate the thorough nature of your review. Your comments regarding the environmental impacts will be responded to in the final environmental impact statement.

Regarding your comments on the geologic features of Millers River, the predominant mineral resources within the basin are sand and gravel deposits. Although peat and other miscellaneous deposits also exist, they are not considered to be typical deposits which should be mentioned in a section dealing with background information. The majority of the project facilities would be deep rock aqueducts. It is not anticipated that the tunnel construction would hinder further mining efforts. We will treat the geological aspects in detail during preconstruction planning.

Regarding the question of conservation measures at Northfield Mountain project, the reports recognize a need for further studies into the utilization of conservation techniques. Such studies will be conducted during the advanced engineering and design phase.

I thank you for your review of these project reports.

Sincerely,

(Signed)

W. C. GRIBBLE, JR.
Lieutenant General, USA
Chief of Engineering

COMMENTS OF THE DEPARTMENT OF TRANSPORTATION

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS:
U.S. COAST GUARD (G-WS/73)
400 SEVENTH STREET SW.
WASHINGTON, D.C. 20590
PHONE: 426-2262

• 5 November 1975

Major General J. W. Morris
Acting Chief of Engineers
Department of the Army
Washington, D. C. 20314

Dear General Morris:

This is in response to your letter of 29 July 1975 addressed to Secretary Coleman concerning a revised draft environmental impact statement on Northfield Mountain Water Supply Project.

The concerned operating administrations and staff of the Department of Transportation have reviewed the material submitted. The Coast Guard had the following comments:

"Since at present the water of the Connecticut River is polluted at Northfield, the cost of improving its quality, by whatever appropriate means, should be included in the cost of the project.

"Even if the Northfield Mountain Project is implemented, the report questions the ability of the existing distribution conduits and aqueducts to handle the increased service. For this reason we feel that the cost of improving the present MDC distribution system to handle the additional water made available should be included.

"It is felt that all available reasonable alternatives have not been mentioned in the report. The use of the Charles River and the Mystic River are not mentioned in the study. No mention is made of the existence of groundwater potential in communities presently served by the MDC.

"A preliminary contingency plan to protect Quabbin Reservoir in the event of an industrial mishap at an upstream papermill or an upstream oil spill on the Connecticut River would be highly beneficial to evaluate the potential consequence of the project.

Subj: Draft environmental impact statement for Northfield Mountain Water Supply Project Survey Report:

"It was found that Section IX of the main report is extremely difficult to read and understand. Appendix F did not improve the problem. Our major difficulty was in understanding the criteria for forming the ten community clusters. If all the towns in each cluster are implied to be similar, we totally disagree with the clustering. For example, in cluster number 5, we fail to understand how a town such as Weston where the average house is valued in excess of $90,000.00 is a moderate income area. This office would suggest rewriting the section.

"In the section on alternatives, a condensed version of the University of Massachusetts report on "Water Usage in Communities served by the Metropolitan Commission" should be included.

"It is hoped that the final statement would have a section dealing with potential population redistribution, if any, from the Boston area to the central areas of Massachusetts if the proposed project is not implemented."

The Department of Transportation has no other comments to make nor do we have any objection to this project. The final statement, however, should address the concerns of the Coast Guard.

The opportunity to review this draft statement is appreciated.

Sincerely

D. J. RILEY
Captain, U. S. Coast Guard
Deputy Chief, Office of Marine
Environment and Systems
By direction of the Commandant

xxx

COMMENTS OF THE ENVIRONMENTAL PROTECTION AGENCY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION I
J.F. KENNEDY FEDERAL BUILDING, BOSTON, MASSACHUSETTS 02203

October 14, 1975

Colonel John H. Mason
Division Engineer
New England Division
Corps of Engineers
U. S. Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Mason:

We have completed our review of the Revised Draft Environmental Impact Statement for the Northfield Mountain and Millers River(Division) Generally, we find the document to be an excellent assessment of the impacts of the proposed project.

An issue which has not yet been addressed is the possible requirement for a National Pollution Discharge Elimination Systems (NPDES) permit. The proposed aqueduct may be a point source discharge into Quabbin Reservoir which requires a NPDES permit. This matter has been brought to the attention of our General Council's office for a determination. During the preparation of the final impact statement, our offices should work jointly toward a resolution to this question.

Other areas of concern to this office regarding the proposed project have been discussed during the development of the reports with your office. We would, however, like to briefly review our concerns within the context of the impact statement process.

1. Because of the high quality of water in Quabbin Reservoir and the fact that it is the major drinking water supply for Eastern Massachusetts, it appears necessary that a continuing and effective water quality monitoring be established. Also, if such a monitoring system should indicate the need, provisions for water treatment should be included in the long range plans.

2. The draft statement recognizes that the proposed "best practicable treatment" of upstream wastewater sources on the Millers River will be required. This degree of treatment may not provide a consistantly high quality of water as would be required for diversion to Quabbin Reservoir. However, this determination cannot be made until the plants are in full operation and an extensive water quality monitoring system is established as indicated in the draft statement.

3. The draft statement mentions the possibility of a "Y" connection in the tunnel aqueduct to Quabbin Reservoir. As indicated previously, we feel that the provision for full diversion of the flow to either the west or middle branch of Quabbin Reservoir would guard against any possible short circuiting of the system. The final statement should more completely discuss the "Y" connection and make a more positive statement as to whether or not the "Y" is part of the proposed plan.

We feel that details regarding an NPDES permit must jointly be resolved and that the final statement should include a more detailed explanation of the monitoring and the "Y" connection for the diversion. We are also concerned about the quality of the water that will be entering the Quabbin Reservoir, because it supplies such a massive water system.

Therefore, in accordance with our National Rating System, we have designated this project as ER-2. A copy of our National Rating System is enclosed.

Please excuse the tardiness of our comments but considering the seriousness and complexity of the project, we were not prepared to submit our comments on September 29, 1975.

Thank you for sending us copies of the draft statement and reports for our review. We would also like to receive a copy of the final impact statement when it is prepared.

Sincerely yours,

Wallace E. Stickney

Wallace E. Stickney, P.E.
Director
Environmental Impact Office

Enclosure

EXPLANATION OF EPA RATING

Environmental Impact of the Action

LO -- Lack of Objections

EPA has no objections to the proposed action as described in the draft environmental impact statement; or suggests only minor changes in the proposed action.

ER -- Environmental Reservations

EPA has reservations concerning the environmental effects of certain aspects of the proposed action. EPA believes that further study of suggested alternatives or modifications is required and has asked the originating federal agency to reassess these aspects.

EU -- Environmentally Unsatisfactory

EPA believes that the proposed action is unsatisfactory because of its potentially harmful effect on the environment. Furthermore, the Agency believes that the potential safeguards which might be utilized may not adequately protect the environment from hazards arising from this action. The Agency recommends that alternatives to the action be analyzed further (including the possibility of no action at all).

Adequacy of the Impact Statement

Category 1 -- Adequate

The draft environmental impact statement sets forth the environmental impact of the proposed project or action as well as alternatives reasonably available to the project or action.

Category 2 -- Insufficient Information

EPA believes that the draft environmental impact statement does not contain sufficient information to assess fully, the environmental impact of the proposed project or action. However, from the information submitted, the Agency is able to make a preliminary determination of the impact on the environment. EPA has requested that the originator provide the information that was not included in the draft environmental impact statement.

Category 3 -- Inadequate

EPA believes that the draft environmental impact statement does not adequately assess the environmental impact of the proposed project or action, or that the statement inadequately analyzes reasonably available alternatives. The Agency has requested more information and analysis concerning the potential environmental hazards and has asked that substantial revision be made to the impact statement.

If a draft environmental impact statement is assigned a Category 3, no rating will be made of the project or action; since a basis does not generally exist on which to make such a determination.

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COMMENTS OF THE FEDERAL POWER COMMISSION

FEDERAL POWER COMMISSION
WASHINGTON, D.C. 20426

IN REPLY REFER TO:

14 April 1976

Lieutenant General W. C. Gribble, Jr.
Chief of Engineers
Department of the Army
Washington, D. C. 20314

Reference: DAEN-CWP-A

Dear General Gribble:

This is in reply to your letter of January 2, 1976, inviting comments by the Commission relative to your proposed report and to the reports of the Board of Engineers for Rivers and Harbors and of the Division Engineers, New England and North Atlantic, on the Northfield Mountain Water Supply Project, Massachusetts. A combined draft environmental statement for the Northfield Mountain and Millers River Diversion Projects accompanied the reports.

The cited reports recommend the construction of conveyance facilities to transmit diverted flows of the Connecticut River from the upper reservoir of the existing Northfield Mountain Pumped Storage Hydroelectric Project to the existing Quabbin Reservoir to assist in meeting the water supply needs of the Boston metropolitan area. The diverted water, consisting of skimmed high flows of the Connecticut River, would be pumped through the facilities of the existing pumped storage project and conveyed to Quabbin Reservoir. The reservoir of the existing Turners Falls Hydroelectric Project serves as the lower pool of the pumped storage project. The diversion of flows would take place only if the flow in the Connecticut River, as measured at the gaging station at Montague City, Massachusetts, is above 17,000 cubic feet per second.

During construction of the Northfield Mountain Pumped Storage Project, the upper reservoir dikes and appurtenant facilities were constructed four feet higher than necessary for the proposed power operation to provide additional storage capacity for the water supply function. In addition, headworks were constructed at the upper reservoir for the proposed water supply diversion aqueduct. The structures necessary to complete the water supply diversion system include 9.8 miles of connecting aqueduct and outlet facilities at Quabbin Reservoir.

The construction cost of the proposed water supply project, including the costs of modifications to the Northfield Mountain Pumped Storage Project which have already been accomplished, is estimated to be $46,815,000.

The Commission staff has reviewed the reports of your Department to determine the effects that the proposed actions might have on matters affecting the Commission's responsibilities. Such responsibilities relate to the development of hydroelectric power and assurance of the reliability and adequacy of electric service under the Federal Power Act, and the construction and operation of natural gas pipelines under the Natural Gas Act.

Review by the staff indicates that the proposed water supply project would not be adaptable to the economical development of hydroelectric power. Also, the project apparently would not affect the transmission of natural gas.

The staff notes that the Turners Falls Hydroelectric Project and the Northfield Mountain Pumped Storage Hydroelectric Project are licensed by the Federal Power Commission and are designated as Project No. 1889 and Project No. 2485, respectively. The original license for Turners Falls has expired and the project is being considered for a new license. The project is presently operating under annual licenses. The Northfield Mountain Pumped Storage Project license will expire in 2018.

Your proposed report states that non-Federal interests should provide assurances that those functions of the pumped storage project which are necessary for the proper operation of the proposed water supply project would be provided throughout the life of the project. In this regard the staff notes that the license for the Northfield Mountain Pumped Storage Project authorizes the licensee to utilize the Turners Falls Reservoir as a source of water and as a lower pool. Both the Northfield Mountain Pumped Storage Project and Turners Falls Project licenses provide for coordinated operation of the two projects. Opinion No. 541 and Order, issued by the Commission at the time the Northfield Mountain Pumped Storage Project was licensed, recognized the joint-use proposal to utilize the Northfield Mountain Pumped Storage Project at some future time to divert high flows in the Connecticut River to Quabbin Reservoir.

The staff review shows that, in order to divert water to Quabbin Reservoir via the Northfield Mountain Pumped Storage Project, the license for the pumped storage project would have to be amended to authorize the Commonwealth of Massachusetts, acting through its Metropolitan District Commission, to make reasonable use of project properties, lands, and waters in the interests of comprehensive development of a waterway for water supply.

The licensee would be compensated for any expenses which the joint-use causes the licensee to incur. Such compensation would be fixed by the Commission upon agreement between licensee and the party or parties benefiting, or upon its own motion after notice and opportunity for hearing.

It should be pointed out that the matter of required facilities for the passage of anadromous fish at the licensed Turners Falls Project is the subject of a current proceeding before the Commission. The draft environmental statement does not discuss the fish passage facilities to be constructed at Turners Falls, nor does it discuss the possible consequences that the proposed water supply diversion would have on shad or Atlantic salmon runs which are planned to be re-introduced into the Connecticut River above the Turners Falls Project following completion of the fishways. Increasing the pumping time to accommodate the proposed water supply diversion would increase the exposure of both anadromous and resident species of fish to the hazards of being drawn through the pumps. The discussion of the impact on aquatic life, as given in the draft environmental statement, does not provide sufficient detail to identify the problems of fish protection at the pumped storage project. Recent fisheries studies at the Northfield Mountain Pumped Storage Project by the Commonwealth of Massachusetts should be useful in revising this discussion.

The draft environmental statement fails to discuss the impacts caused by the generation of electrical energy needed to pump the water for the proposed water supply project from the Connecticut River to the Northfield Mountain upper reservoir.

Presumably, the skimming operation of the proposed water supply project would have little or no effect on the power generated at hydroelectric plants located downstream on the Connecticut River, many of which are licensed by the Commission. However, it is suggested that this matter be discussed in the draft environmental statement.

Based on its consideration of the reports of your Department, the draft environmental statement, and the studies of its own staff, the Commission concludes that the proposed Northfield Mountain Water Supply Project would not provide opportunity for the development of hydroelectric power. It notes that the proposed project would affect the licensed Northfield Mountain Pumped Storage Hydroelectric Project and, therefore, would require consideration and action by the Commission. It suggests that the draft environmental statement discuss the effects of the proposed project on Connecticut River fisheries, on the supply and consumption of energy for pumping, and on generation at downstream hydroelectric projects.

Sincerely yours,

Richard L. Dunham
Chairman

COMMENTS OF THE NEW ENGLAND RIVER BASINS COMMISSION

NEW ENGLAND RIVER BASINS COMMISSION

55 COURT STREET • BOSTON, MASSACHUSETTS 02108
PHONE (617) 223-6244

April 16, 1976

J.W. Morris
Major General, USA
Acting Chief of Engineers
Department of the Army
Washington, DC 20314

Dear General Morris:

With regard to your letter of July 29, 1975, we have completed a review of two components of the Northeastern U.S. Water Supply (NEWS) Study, the Northfield and Millers River Water Supply Project Survey reports, as well as a review of the Revised Draft Environmental Statement on these projects. I am sorry that we were not able to send these comments to you sooner.

As you may know, two of the Commission's Level B studies, the Connecticut River 1980 Basin Plan (1972) and the Southeastern New England (SENE) Study (1975) deal with the donor and recipient areas, respectively, for each of these diversion projects. A copy of the recently released Regional Report of the SENE Study is enclosed. Chapter 4 of this report, especially pages 4-14 through 4-22 and Recommendation #13, details the Commission's position on the Northfield Mountain and Millers River Basin projects. Although both diversions are conditionally recommended in the Connecticut River Basin Plan and in the SENE Study, the recommendations and conclusions of these reports differ somewhat from the findings of the NEWS Study. Our specific comments are as follows.

1. In a section of the SENE Study dealing with the water supplies of communities served by the Metropolitan District Commission (MDC), the figures for water supplies and demands differ significantly from the figures presented in both the Northfield and Millers River reports. According to the SENE Study's projections, the MDC communities would require an additional 78 million gallons per day (mgd) by 1990, rather than the requirement of 141 mgd predicted by the NEWS reports. This difference can be important when considering the timing and the need for further research on the alternatives to and the impacts of the Millers River Basin project.

2. Regarding alternatives to the Northfield Mountain and Millers River Basin projects, the findings of the SENE Study support, but would give even greater emphasis to, conclusions in both NEWS reports that accelerated

research efforts should be carried out regarding (1) the use of pricing as a mechanism of water demand management, (2) the value of public education as a means to encourage water conservation, (3) the cost-effectiveness of water saving devices, and (4) the elimination of health hazards in recycling treated wastewater for domestic use. In addition, the SENE Study emphasizes the potential of industrial recycling of wastewater and the need to change the rate structure for high volume water users in order to increase the amount of publicly supplied water available for domestic use.

While in agreement with the NEWS report findings that there are presently economic and environmental problems concerning desalination, the SENE Study recommends increased research into the techniques of economically feasible, environmentally safe desalination as a long-range method of meeting Southeastern New England's water needs.

Both the NEWS and SENE studies consider Plymouth County ground water supplies as an alternative source of water for the MDC. However, unlike the NEWS Study, which rejects this alternative on the basis of its cost, the SENE Study has found that most of the Plymouth County supplies would probably be needed to meet local, in-basin needs. This finding is also consistent with the SENE Study's overall principle of encouraging local use of water supplies over interbasin transfers.

Problems of poor water quality in the Merrimack River and the expense of its treatment lead both the NEWS and SENE studies to view this source of supply only as a long-range alternative to meet the MDC's needs, and the SENE Study endorses continuing study of this option. Again, however, the implications of interbasin transfers will have to be carefully considered.

The NEWS Study has stated that development of a diversion from the Sudbury River would be fully compatible with the Northfield Mountain and Millers River Basin projects. Because definitive information on this alternative has not been developed as yet, the SENE Study was not able to recommend the diversion as a short term source of supply. If, as the MDC has estimated, an additional 40 mgd could be made available from this source in the near future, this amount, combined with the water from the Northfield Mountain diversion, could be sufficient to meet the MDC's 1990 needs as projected by the SENE Study. If the MDC's estimates prove to be correct, they could affect the timing of the Millers River Basin project.

3. In discussing the need for the Northfield Mountain and Millers River Basin diversions, the NEWS reports do not mention the adequacy of the MDC communities' distribution systems. A recent study, prepared for the MDC by the Water Resources Research Center at the University of Massachusetts and Curran Associates, Inc., reports that if leaks and breaks in the MDC

communities' distribution systems which exceeded 3,000 gallons per mile of main per day were corrected, 47 mgd or more might be saved. The findings of this report should be investigated and verified.

4. From another point of view, the Commission's 1980 Connecticut River Basin Plan has considered the needs of the communities along the Connecticut River below the diversion sites -- the "donor" areas. The Plan recommends that all diversions from the basin be conditioned on water quality monitoring and recognition of the basin communities' riparian rights, specifically the right of return of these waters when they are needed for water supply or flow augmentation. In addition, the report recommends the Millers River Basin project or other diversions only if certain conditions are met: (1) establishment of an appropriate water allocation mechanism in which downstream states have a voice, (2) prior evaluation of a diversion's economic, environmental, and social impacts, (3) continued water quality monitoring, and (4) determination of the adequacy of Connecticut Valley ground water resources. The SENE study endorses these recommendations and predicates its approval of the Northfield Mountain and Millers River Basin projects on the fulfillment of the 1980 Basin Plan's conditions.

5. With regard to the water allocation mechanism mentioned above, the Commission has received copies of the Chief of Engineers' proposed reports on the Northfield Mountain and Millers River Basin components of the NEWS Study. In his reports, the Chief of Engineers states that it will not be necessary to stipulate the establishment of an agreement between Massachusetts and Connecticut on the diversion issues as a condition for federal participation. However, the Board of Engineers for Rivers and Harbors, in giving reasons warranting federal participation in funding the project, has also, in our opinion, given reasons which show the necessity of an agreement between the two states before federal loans are made. The statements (DAEN-BR (25 Oct 74) 2d Ind Northfield Mountain Survey Report (p. 5) and DAEN-BR (25 Oct 74) 2d Ind Millers River Survey Report (p. 7)) include the following:

> "The project(s) would have interregional and interstate impacts (emphasis added);
>
> "The project(s) involves regional equity issues (emphasis added);
>
> "The project(s) involves resolution of interbasin water transfer issues" (emphasis added).

For these reasons the federal government should require that Connecticut and Massachusetts establish a regional mechanism, if feasible, or other appropriate arrangement to allow downstream interests a voice in water supply allocation before federal participation in the Northfield Mountain or Millers River Basin projects is approved.

6. An overall impression given by Section 3 of the Revised Draft Environmental Statement is that the discussions of the diversions' environmental impacts are not, in many cases, supported by quantitative data. Too often, the terms "postulated," "anticipated," "expected," and "speculated" are used to replace hard facts and figures. This language is particularly disturbing in the case of the Millers River Basin project, where it is estimated that as much as 55 and 74 percent of the Millers and the Tully Rivers' flow, respectively may be diverted during an average year (Environmental Statement, pp. 62 and 65). In both cases, the environmental statement asserts that "in no case would the flow in the river be reduced below the established rate necessary to protect the river environment" (pp. 62, 65). The absence of any information which would confirm this assertion should certainly be corrected.

In conclusion, while the SENE Study recognizes the need for the Northfield Mountain and Millers River Basin projects, concern for the consequences of diversion in the donor area and for consistency with the 1980 Connecticut River Basin Plan requires that the projects satisfy the economic, environmental, and social criteria listed above. Moreover, it would appear that additional research is needed into the leakage of the MDC communities' distribution systems, the development of the Sudbury River, and the overall environmental impacts of the Millers River Basin project. Assuming the accuracy of the SENE Study's water supply and demand projections, there would be time for additional research on the above issues before the Millers River Basin Project is needed.

Finally, the SENE Study's general recommendation of encouraging the development of water supplies to meet in-basin needs rather than the continuation of interbasin transfers must be seriously considered when investigating future sources of water for the Boston metropolitan area. Long range alternatives such as desalination and wastewater reuse should be vigorously pursued in order to eliminate the future reliance of MDC communities on additional interbasin transfers of water.

Thank you for the opportunity to comment.

Sincerely yours,

Frank Gregg
Chairman

cc: Horace H. Brown
Joseph N. Gill
David Harrison
Joseph Ignazio
Charles F. Kennedy
John H. Mason
George E. McAvoy
James Minnoch
Kenneth Murdock
Evelyn F. Murphy
Julia O'Brien
Hugo F. Thomas
Bette Woody

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT SURVEY REPORT

REPORT OF THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

REPLY TO ATTENTION OF:

DAEN-CWP-A

10 September 1976

SUBJECT: Northfield Mountain Water Supply Project Survey Report

THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my report on the Northfield Mountain water supply project, accompanied by the report of the Board of Engineers for Rivers and Harbors and the reports of the Division Engineers, New England and North Atlantic, in partial response to the Northeastern United States Water Supply Study legislation enacted 27 October 1965, under Title 1 of Public Law 89-298, requesting the Secretary of the Army, acting through the Chief of Engineers, to prepare plans to meet the long-range water supply needs of the Northeast.

2. The Division Engineers find that the water supply needs of the Boston metropolitan area are both of a critically urgent and regional nature, to the extent that it is in the national interest for the Federal Government to participate in assuring the adequacy of the region's water supply sytem. Accordingly, the Division Engineers recommend construction of conveyance facilities to transmit diverted flows, skimmed during flood stages on the Connecticut River, to the existing Quabbin Reservoir from the upper reservoir of the Northfield Mountain pumped storage hydroelectric power facility. They estimate the first cost of the proposed improvements to be $46,815,000. Based on an interest rate of 5-7/8 percent and a 50-year period for economic analysis, total annual charges are presently estimated at $4,083,000, including $907,000 for maintenance, operation, and replacements. Losses prevented by implementation when compared to project costs yield a benefit-cost ratio of 1.1 under normal runoff conditions and 1.7 under assumed drought conditions. The reporting officers recommend the general repayment provisions of the Water Supply Act of 1958, as amended, as the basis for cost sharing in the proposed project.

3. The Board of Engineers for Rivers and Harbors concurs in general in the views and recommendations of the reporting officers. The Board believes, however, that the estimated total first cost of the project should not include the cost of $2,000,000 for the existing diversion

facilities at the upper reservoir of the Northfield Mountain pumped storage facility, and that the appropriate amount should be $44,815,000. Furthermore, the Board believes that non-Federal interests should provide assurances that those functions of the Northfield Mountain pumped storage hydroelectric facility which are necessary for the proper operating of the proposed project will be provided throughout the life of the project. The Board also believes that it is not necessary or desirable to stipulate establishment of an agreement between the States of Massachusetts and Connecticut regarding Connecticut River diversions as a condition for Federal participation in this project, and is convinced that any potential project-related jurisdictional claims can be approached best through the mechanism of requiring non-Federal interests to hold and save the United States free from damages due to water rights claims.

4. The estimated first cost of the project is $44,815,000. The annual charges are presently estimated at $3,947,000, including $907,000 for operation, maintenance, and replacements. Annual benefits are $4,354,000 and $6,803,000 for average runoff and drought runoff conditions, respectively. The resultant benefit-cost ratios are 1.1 and 1.7.

5. Reformulation in accordance with the Water Resources Council's Principles and Standards, which became effective on 25 October 1973, would not have sufficient effect to change the findings of this report. The Addendum required by the Water Resources Council Procedure Number 1 is inclosed.

6. I concur in the views and recommendations of the Board. Use of the currently prescribed interest rate of 6-1/8 percent would have insignificant effect on the benefit to cost ratio.

1 Incl
Addendum

R. C. MARSHALL
Major General, USA
Acting Chief of Engineers

Addendum

Northfield Mountain Water Supply Project
Northeastern United States Water Supply Study

I. Introduction.

The recent drought of the sixties in southeastern New England caused many water supply systems to re-evaluate the dependable yield which their facilities could produce. In many cases, the new dependable yield was significantly less than previously estimated. In turn, water demands on these same systems have been increasing; therefore, additional supplies are necessary.

The 89th Congress recognized that the assurance of adequate supplies of water for the great metropolitan centers had become a problem of such magnitude that the welfare and prosperity of the United States required the Federal Government to assist in its resolution. Consequently, the Congress enacted the Northeastern United States Water Supply (NEWS) Study on 27 October 1965, under Title I of Public Law 89-298.

The NEWS Study Act authorized the Secretary of the Army, acting through the Chief of Engineers, to prepare plans to meet the long range water supply needs of the Northeast, in cooperation with Federal, State and local agencies. The Chief of Engineers, in turn, assigned responsibility for the NEWS Study to the Division Engineer, North Atlantic.

During the preparation of the NEWS study certain urgent need areas have been identified as requiring early augmentation of existing supplies. The Northfield Mountain Water Supply Project is designed to provide water to one of these urgent need areas, namely the eastern Massachusetts and Rhode Island region.

The Northfield Mountain Water Supply Project was formulated prior to the adoption of the Principles and Standards.

During the plan formulation for the subject project, however, it was recognized that the Principles and Standards would probably be adopted prior to authorization of the project. As a result, the

Proposed[1] Principles and Standards were followed and benefits as well as losses were evaluated on a three account system.

The current Principles[2] and Standards differ somewhat from the earlier proposed version. In the main, however, the accounting system is quite similar to that used in the Northfield Mountain Water Supply Project report.

One area in which the current Principles and Standards differ from the technique used in the subject report is the requirement for a separate Environmental Quality plan. In the subject report, the recommended project is the result of a mix of a National Economic Development plan and an Environmental Quality plan. This mix plan was the result of public participation and the use of an interagency interdisciplinary team during the plan formulation, assessment and evaluation phases. In the sections which follow, therefore, the recommended plan is considered to be the EQ plan.

II. Planning Objectives.

The objective of the overall NEWS Study is the preparation of a coordinated general plan for essential water supply development in the Northeast which will recommend to the Congress an active program for Federal, State, local and private organizations. It thus provides a public forum where all vitally concerned with the water supply problems of the area can be heard in developing a plan to resolve one of the many domestic problems now facing the United States.

In achieving its objective, the NEWS Study will present a regional assessment of present and future water supply needs and will present alternatives for their solution. The study effort is being fully coordinated through the various Federal, State, local and private

[1] Federal Register, Volume 36, No. 245, Part II Water Resources Council -- Proposed Principles and Standards for Planning Water and Related Land Resources.

[2] Federal Register, Volume 38, No. 174, Part III Water Resources Council, Principles and Standards for Planning Water and Related Land Resources.

agencies and organizations. Such coordination assures that plans are consistent with, and integral to, other concurrent water resource planned development being formulated. During the study, interim reports will be prepared to deal with critical problems which may be encountered. These reports will contain specific recommendations to the Congress for authorization of major reservoirs, conveyance facilities, or treatment facilities, as may be appropriate. The Northfield Mountain Water Supply Project is such an interim report.

III. Summary of Study Area Concerns.

A significant concern within the study area is the State of Connecticut's view of both the Northfield Mountain and Millers River Basin Water Supply Projects. As expressed in correspondence from Governor Thomas Meskill, the prime concern is for "establishment of an interstate mechanism which would insure that the interests of Connecticut and any other affected states would be given proper consideration."

Other concerns which have been expressed regarding the Northfield Mountain Water Supply Project include:

Alternative projects have not been fully considered;

The project would divert water which may be needed in the future by valley residents;

Environmental considerations have not been evaluated fully;

A fair market value should be paid for water diverted;

Water conservation techniques should be instituted within the study area;

Water quality monitoring programs should be instituted to insure a safe drinking water.

Organizations which have expressed all or a part of the above concerns include:

Bureau of Outdoor Recreation

Connecticut Department of Environmental Protection

Franklin County Department of Planning

City of Hartford, Connecticut

Natick, Massachusetts Conservation Commission

Connecticut Audubon Council, Inc.

Connecticut Forest and Park Association, Inc.

Connecticut River Watershed Council, Inc.

Lower Pioneer Valley Regional Planning Commission

Massachusetts Audubon Society

Connecticut River Ecology Action Corporation

League of Women Voters of Massachusetts

Lake Cochituate Watershed Association, Inc.

Save Our Streams

Mr. C. Russell Shaw, New Salem, Massachusetts

Jean A. Simoneau

David W. Stickel, Holyoke, Massachusetts

Sierra Club, New England Chapter

and Connecticut River Basin Task Force.

IV. Description of the Recommended Plan.

Authorization for construction of the diversion facilities from Northfield Mountain to Quabbin Reservoir has been granted to the Metropolitan District Commission by the Massachusetts State Legislature. Recognizing this fact, the representatives of the Federal, State and local agencies and interests at the May 1970 meeting recommended that the Corps of Engineers investigate the project as a very viable element in any regional water supply plan for Southeastern New England. It was further recommended that the NEWS studies be designed to complement those under way or planned by the Metropolitan District Commission.

The Northfield Mountain Diversion project would use a high flow skimming technique; that is, flow would be diverted during high flow periods, principally during spring run-off periods. Water would be diverted from the Connecticut River through the Northfield Mountain pumped storage hydroelectric facility located in Northfield and Erving, Massachusetts. As a means of control, diversions would not occur if flow in the Connecticut River at Montague City U. S. Geological Survey gaging station is less than 17,000[1] cubic feet per second or about 11,000 million gallons per day.

The pumped storage project for electricity generation consists of a high level storage reservoir on Northfield Mountain, underground pump-turbine facilities and low level storage in the Turners Falls pool. The high level reservoir consists of a system of dams and spillways to provide 17,000 acre-feet of storage, about 800 feet above the Turners Falls pool on the Connecticut River.

In order to provide the water supply diversion volume, the electric utility would pump an additional 375 million gallons each day that control flows in the Connecticut River would allow. The additional yield which could be made available by this plan would be 84 million gallons per day on a long term average annual basis. Because of operational considerations, however, the yield estimated to be made available to Quabbin Reservoir is about 72 million gallons per day.

[1] This control flow is specified in the current Massachusetts State Legislation regarding the Northfield Mountain Project.

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In order to incorporate the water supply diversion into the Northfield Mountain Project, three modifications to the pumped storage facilities are necessary. These are:

(1) Raising the upper reservoir located on Northfield Mountain about 4 feet to provide about 50,000,000 cubic feet of additional storage capacity. (completed by utility company).

(2) Provision of headworks at the upper reservoir for the diversion aqueduct to Quabbin Reservoir. (completed by utility company).

(3) About 9.8 miles of connecting aqueduct and outlet facilities at Quabbin Reservoir.

The first two items necessary for water supply diversion have been essentially completely constructed at the upper reservoir on Northfield Mountain by the electric utility construction forces.

The third item necessary for water supply diversion is presently in preliminary design stages by engineers at the MDC. At present, plans indicate water would be diverted from the upper reservoir through an eight-foot diameter steel pipe constructed in the east dike of the Northfield Mountain upper reservoir. Water would be withdrawn at an average rate of 375 million gallons per day and delivered to an intake shaft of the Northfield - Quabbin tunnel aqueduct.

The intake down shaft would be a scroll type configuration with a diameter of 16 to 18 feet. The aqueduct itself would be a 10-foot finished diameter tunnel with a reinforced concrete liner.

Cost estimates for the water supply facilities including the raising of the upper reservoir at Northfield Mountain, intake works, connecting tunnel aqueduct to Quabbin Reservoir and outlet works would total about 47 million dollars. Modification of the upper pool has been completed at a cost of 2 million dollars by the utility company and is not a part of the project proposed for authorization which would now cost 45 million dollars.

1) Water Treatment Required

The quality of the Connecticut River varies depending upon upstream municipal and industrial waste discharges, river flow, velocity, time of year and other considerations. The river's water quality in the vicinity of the Northfield intake has been tested by a number of Federal and State agencies. In addition, testing of the water quality, reported upon in Appendix D, was conducted as part of this study.

Upon analysis of available data, it was concluded that no water treatment is necessary prior to the diversion of Connecticut River water to Quabbin Reservoir. This conclusion is based on the assumption that proper water quality monitoring of Connecticut River water would be performed in the interim years during construction as well as during actual diversion periods and that planned pollution abatement plants will be constructed and in operation.

To safeguard Quabbin itself, the option of including a dual outlet system has been considered. To provide for this future flexibility, if needed, the Northfield - Quabbin aqueduct would include a tunnel stub heading toward the West Branch of the reservoir. If needed in the future, because of water quality considerations, the remaining portion of this tunnel could be constructed.

2) Waste Treatment Required

Water quality investigations indicate that the Connecticut River can be used as a supply source after reservoir storage detention and adequate measures for disinfection. If pollution loads upstream from the Northfield intake continue unchecked, however, there is no assurance that the quality will remain satisfactory.

The Environmental Protection Agency, in cooperation with the New Hampshire Water Supply and Pollution Control Agency and the Vermont Division of Water Supply and Pollution Control, has established an implementation schedule for abatement of pollution discharges upstream from the diversion intake at Northfield. This implementation schedule[1] calls for secondary waste treatment

[1] The coordinated draft Environmental Impact Statement was completed in January 1974.

facilities to be constructed and in operation by 1976. Adherence to this established schedule is vital to the quality of the Connecticut River water which is to be diverted for water supply purposes. If the schedule is not adhered to, the potential for increased pollution loads hindering the use of the river as a water supply source is a strong possibility.

V. Impact Assessment and Evaluation.

In the formulation and selection of plans, a determined effort has been made to involve the public in the decision-making process. Progress, information and public meetings were held throughout the conduct of the study. Audience input gained at these meetings contributed significantly to the work.

Since the initiation of this work, a determined effort has been made to inform the public of the work's progress. Nine progress meetings were held in the Boston Metropolitan area, generally at Waltham, Massachusetts; the first held on 7 May 1970, with the latest held on 7 June 1972. Attendance at these meetings generally averaged about 50 people, with attendees representing Federal and State Agencies, conservation commissions, the Audubon Society, sportsmen groups, and interested citizens.

In addition to the progress meetings, four informal information meetings have been held within the Millers River Basin. These meetings were held in Athol, Massachusetts on 21 October 1971 and 4 January 1972; in Winchendon, Massachusetts on 2 March 1972; and in Athol, Massachusetts on 8 May 1972.

During December 1971 and January 1972, a series of four formulation stage public meetings were held in Needham, Woburn, Orange and Longmeadow, Massachusetts. These meetings were designed to broaden public participation in the open planning process by describing the on-going studies and receiving audience input.

In July 1972, two late stage public meetings were held at Waltham and Orange, Massachusetts, and the various plans for augmenting water supply systems were discussed and described.

A full description of the coordination held during the study is included in the main report and Appendix H.

The evaluation of the project's impacts was accomplished using the three account system proposed earlier by the Water Resources Council. Under the Council's proposed guidelines, at that time, the overall purpose of the project is measured with regard to enhancing National Economic Development, Environmental Quality, and Regional Development.

In order to assess the project's impacts, studies on engineering, socio-economic[1] and environmental[2] considerations were examined. Since the project under consideration involved transfer of a resource through inter-basin diversion, impacts were investigated for both source and receiver areas.

Impacts are quantified and translated into dollar values where possible. In those cases where impacts are not quantifiable, the effects of the project are discussed such that the reader will be aware of all the ramifications of implementing the project.

Apart from the few physical structures proposed, the natural character of the area will remain unchanged. The bulk of surface work will come in remote wooded areas with a minimum of disruption to local traffic patterns. Evidence of the tunneling to Quabbin from Northfield will be seen primarily as access shafts in three or four locations and spoil disposal sites which have not as yet been identified.

From an economic standpoint, changes relate chiefly to the job openings stimulated by construction. Two qualifying points must be made, though, to establish a proper perspective on a labor influx. First, the project will require about 500 men, a comparatively small number with respect to the much larger work forces assembled at the Vermont Yankee Nuclear power generating plant and the Northfield Mountain pumped storage project now under construction. Experience indicates that even if this number were to be larger than the Vernon case, it is unlikely that the supplier area would suffer any adverse effects, e.g., school over-crowding, housing shortages, transportation snarls, etc. As a second mute on impacts, it may be that workers at the Vernon nuclear and Northfield hydroelectric project will move on to the water supply project.

[1] Background data contained in Appendix F.

[2] Background data contained in Appendices D and E.

Apart from relatively small economic impacts, social impacts relating to supplier area residents' perceptions of equity are particularly significant. The source area feels a kind of moral outrage at being "forced to give up our water." The statements of their spokesmen sound a sense of frustration with the present system of water allocation decision-making. The personification of this attitude was observed at all of the NEWS Public Meetings held within the Connecticut River Basin. At these Public Meetings, both this report's project and a companion project in the Millers River Basin (the subject of a separate report) came under fire by local opposition. However, of the two projects, the Millers River Basin plan drew the heaviest antagonism.

On the other hand, development of the Northfield Mountain water supply project would insure protection from water shortages and associated social and economic losses. Estimates of economic losses prevented by project implementation when compared to project costs indicate the project to be economically efficient. With respect to the Regional Development objective, the project would provide a benefit/cost ratio of 1.3 under average runoff conditions; and under a hypothetical drought situation, this ratio was estimated to be 1.9. In the National Economic Development account, concrete losses prevented by implementation compared to project costs yields a benefit/cost ratio of 1.1 under normal and 1.7 under drought runoff conditions.

If the project was not implemented, social costs as well as economic costs could be expected in the receiver communities. Social impacts in the receiver area are principally "shadow costs" of concrete losses generated by water shortage. As municipal efforts turn to finding new sources, building bans to hold the line on new demand are a likely eventuality. Second-order effects of expenditures on water searching manifest themselves as slowed school building programs, poorer municipal services (especially fire protection) and a general malaise in the development plans of the subject town. In many ways, these effects are reflected in attitudes about the desirability of the town as a place to live and work. The net result is stagnating growth, hostility toward the communities which snare the industries unable to locate in a water-deprived town, and a growing dependence on MDC admission as the ultimate solution to water shortage.

From the outset, this study made a determined effort to evaluate the impact which the Northfield Mountain water supply diversion might have on Environmental Quality. An analysis was made regarding impact on the Connecticut River Estuary, on the Connecticut River downstream from the point of diversion, and on the environment of the receiving water storage reservoir.

In general, as described in the main report and fully in Appendices D and E, impact caused by the diversion on the estuary and Connecticut River itself is expected to be minimal. The primary reason for this lack of environmental impact is the relatively small amount of water when compared to river flow which would be diverted.

In evaluating environmental impact on Quabbin and Wachusett Reservoirs, field and laboratory data included about 100 parameters, including chemical, physical, biological and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information and pollution abatement plans were considered and evaluated.

Central to the evaluation was a qualitative model of reservoir dynamics. If water of lower quality such as that in the Connecticut River is introduced to a high quality supply like Quabbin Reservoir, there will most likely be a loss in the reservoir system. A number of parameters including turbidity, chemical oxygen demand, dissolved oxygen and nutrients such as nitrogen and phosphorous received close attention.

Within the receiving water body at Quabbin, the diverted flow may have impacts, but these possible impacts depend to a large degree on what engineering steps are taken prior to the actual diversion. For example, the present waste loads in the river may provide opportunities for algae growth or oxygen depletion. However, if current pollution abatement schedules are followed and the goals of the Water Quality Act of 1972 attained, then present loadings in the river will be reduced; and as a consequence, the probability of possible damage to Quabbin also minimized.

On the other hand, if no additional water is made available to the reservoir, then increased demands may deplete available storage. Declining storage volumes, in turn, will cause an overall loss in water quality. In addition to this possible reservoir water quality deterioration caused by reduced storage levels, supply shortages in

the receiver area could also cause a loss in environmental quality for those communities served by the system.

Although exact quantifications of all potential impacts could not be defined, basically because of the present state of the art of ecological investigations, the relative probability of impacts occurring was defined. A summary of these impacts is included in the main report, and a full description of the studies is given in Appendix D -- Water Quality Studies of Connecticut and Millers Rivers and Quabbin and Wachusett Reservoirs.

Followup studies of those parameters which require further detail are presently under way with sponsorship from the Metropolitan District Commission.

Finally, if the project was implemented, the additional water supplied would be returned as waste water. If this effluent was not treated adequately, it could cause a degradation of water quality in the receiver area. However, the Water Quality Act of 1972 calls for full treatment of waste discharges by the early 1980's.

VI. Summary of Unresolved Problems.

Environmental groups have stated that additional environmental studies are necessary. Although further study on any issue may aid the final decision, it is the belief of the Division Engineer that sufficient study has been conducted such that a rational decision may be made on the project under consideration.

It is understood that the project, if authorized, would undergo further environmental investigations during the advanced engineering and design phase. These studies would be designed to provide further information on concerns expressed by the various environmental groups.

VII. Mitigation Measures.

In formulating the project, the effects of the project on the environment were considered and minimized where possible. A prime example of this engineering - environmental interplay is depicted by the control flows adopted for use in the project.

In the Connecticut River, a flow rate of 17,000 cfs would be required before any diversion could take place. As a result of the adopted control flow rates, the effect of the project on the environment downstream has been minimized. The control flows as developed, however, do not allow for maximum economic use of the facilities. Thus, in this regard, they can be considered as mitigation measures.

VIII. Determination of Need for Reformulation.

Although the current Principles and Standards were not used directly in the report, we believe there is no need for reformulation of the subject report, as the use of the earlier proposed Water Resources Council guidelines provided a good basis for decision in consonance with current requirements.

Northfield Mountain Water Supply Project

Northeastern United States Water Supply Study

Estimated Project Costs = $44,815,000 (October 1974)

	National Economic Development				Regional Development			
	Using Current Value		Water Resource Council		Using Current Value		Water Resource Council	
Interest Rate	5-7/8%		6-7/8%		5-7/8%		6-7/8%	
Period of Analysis*	50 years		50 years		50 years		50 years	
	Average Runoff	Drought Runoff	Average Runoff	Drought Runoff	Average Runoff	Drought Runoff	Average Runoff	Drought Runoff
Annual Plan Benefits (water supply)	4,354,000	6,803,000	4,102,000	6,917,000	4,950,000	7,644,000	4,730,000	7,775,000
Annual Plan Costs	3,947,000	3,947,000	4,433,000	4,433,000	3,947,000	3,947,000	4,433,000	4,433,000
B/C Ratio	1.1	1.7	0.9	1.6	1.3	1.9	1.1	1.8

*Although 50 years was used as the period of analysis, it should be noted that the project is almost entirely comprised of features which have an extended life.

DAEN-BR (25 Oct 74) 2d Ind
SUBJECT: Northfield Mountain Water Supply Project Survey Report

Board of Engineers for Rivers and Harbors, Fort Belvoir, Virginia 22060
21 March 1975

TO: Chief of Engineers, Department of the Army

1. This interim report is in partial response to Title I of Public Law 89-298, enacted on 27 October 1965, authorizing the Northeastern United States Water Supply Study (NEWS). Title I was enacted because of Congressional interest in the effect of the drought of the 1960's in the northeastern United States, and recognition that adequate water supply for the great metropolitan centers had become a problem of such magnitude that the welfare and prosperity of the Nation required the assistance of the Federal Government.

2. During the NEWS study, certain areas were identified as requiring early augmentation of existing supplies. The Northfield Mountain diversion project is proposed to meet the urgent needs of the southeastern Massachusetts and Rhode Island region. It was one of the alternative projects considered to provide the next unit in the largest regional water supply system in the area, operated by the Metropolitan District Commission (MDC) of the State of Massachusetts and serving the Metropolitan Boston area. It would provide the additional water supply for the MDC by diverting high flows, above an established flow level, from the Connecticut River through the existing Northfield Mountain pumped storage hydroelectric power project into Quabbin Reservoir, which is located within the Connecticut River Basin and is the main water supply storage facility in the existing system.

3. The Connecticut River Basin encompasses an area of about 11,250 square miles, of which 114 square miles are located in the Province of Quebec, Canada. The river has a length of more than 400 miles from the Canadian border to the tidal waters of Long Island Sound. The basin has a maximum width of 60 miles, and includes land in four States. More than 200 dams, each controlling more than 50 square miles of drainage area, exist within the basin, including 16 flood control reservoirs constructed by the Corps of Engineers. The basin also has hundreds of native lakes and ponds.

4. The source and service areas covered in the study are economically dissimilar. The source area, Franklin County, Massachusetts, is predominantly rural. Since 1900, however, manufacturing has contributed heavily to the local economy of the central and eastern sectors of the county. The major manufacturing products are fabricated metals, textiles, paper, and processed food. Agriculture, once Franklin County's most thriving industry, is rapidly declining in terms of employment. This decline is due to the rising value of farmland in alternative uses, resulting from expanding urbanization and the accompanying high taxes and wage levels.

5. The service area is principally the densely urbanized area of Boston and its suburbs. The Boston metropolitan area is the largest employment and population center in New England, and is the northern terminus of the Atlantic coast megalopolis extending between Boston and Washington. Boston is the largest city in New England, and is the center of the eighth largest Standard Metropolitan Statistical Area (SMSA) in the United States. The city's primary function is that of a trade and finance center. Manufacturing, however, has the largest share of total employment, followed by the service industries. In recent years, Boston experienced a remarkable growth in technologically-oriented industries which located in the area to take advantage of the concentration of advanced education and research facilities.

6. The regional water supply system operated by MDC supplies 42 communities within the Commonwealth of Massachusetts. Consumers number about two million persons, or 37 percent of the State's 1970 population. To meet its water supply needs, the MDC relies upon three major reservoirs, Quabbin, Wachusett, and Sudbury, which are located on the tributaries of the Connecticut and Merrimack Rivers. Quabbin Reservoir is the keystone of the system, and impounds flows from 186 square miles of the Swift River and 96.8 square miles of the Ware River.

7. The recent drought in southeastern New England directly affected the water use patterns of more than 20 million people. In 1965, drought-related water shortages were severe enough to warrant emergency actions. Within Massachusetts, more than 50 cities imposed restrictions on water use. Because of the severity of this drought, many water supply utilities were required to reevaluate the dependable yield which their facilities could produce. In many cases, it was found that dependable yield was significantly less than previously estimated. Furthermore, the water demands on these same systems have been increasing. In the study area, the difference between dependable yield of existing systems and the projected demand is expected to increase from 136 million gallons per day (m.g.d.) in 1980 to 910 m.g.d. in 2020. The estimated dependable yield from existing MDC sources of supply is about 300 m.g.d. In 1971, the average daily demand of all communities serviced by the system exceeded the available long-term dependable yield. Forecasts of demands on the system for 1990 indicate an additional 141 m.g.d. will be necessary to satisfy MDC customers unless water use practices of the service population are altered dramatically.

8. Formulation of plans for meeting the long-range water needs of eastern Massachusetts and Rhode Island included: consideration of local and imported water supplies from the Connecticut, Merrimack,

and St. Lawrence Rivers; development of newer technology, such as desalination; institutional means for reducing water demand; and improved efficiency of existing sources and systems. The major criteria emphasized in plan formulation were least cost, system reliability and flexibility, timeliness, minimum adverse environmental impact, and regional dependency. Also, the objectives of National Economic Development and Environmental Quality Enhancement were considered, and the benefits and losses resulting from the plan were evaluated for national economic development, environmental quality, and regional development.

9. Planning investigations revealed that early augmentation of the MDC system was the most urgent need in the region. The Northfield Mountain and Millers River diversions from the Connecticut River Basin were found to be the most desirable next increments and were selected for recommendation as the first elements for Federal participation under the NEWS authority.

10. The Northfield Mountain diversion project would provide for diversion of Connecticut River flows, during periods when flow at Montague City gaging station is greater than 17,000 cubic feet per second (c.f.s.) or about 11,000 m.g.d. through the existing Northfield Mountain pumped storage hydroelectric power facility, owned by Northeast Utilities, to Quabbin Reservoir. The project would increase MDC system yield by about 72 m.g.d., on an average annual basis. The pumped storage reservoir has already been modified to accommodate the diversion by increasing its capacity by about 1,150 acre-feet and construction of the head works for the diversion tunnel to Quabbin Reservoir. The remaining portions of the project consist of a 10-foot diameter concrete-lined tunnel about 9.8 miles long, from the pumped storage reservoir to Quabbin Reservoir, and outlet works in Quabbin Reservoir.

11. The total project cost, including the cost of the completed modification at the Northfield Mountain hydroelectric facility, is estimated to be $46,815,000, based on July 1974 price levels. The average annual costs, based on an interest rate of 5-7/8 percent and a 50-year period for economic analysis, are $4,083,000, including $907,000 for maintenance, operation, and normal replacements. In the National Economic Development account, economic losses prevented by Northfield Mountain water would result in a benefit-cost ratio of 1.1 under normal conditions and 1.7 under assumed drought conditions.

12. The reporting officers conclude that the urgent needs of the Metropolitan Boston area are regional in nature, and that it is in the national

repayment provisions of the Water Supply Act of 1958 should be the basis for cost sharing in the proposed project. Additionally, the Division Engineer, New England, recommends that studies be conducted by the Federal Government to assess the impact that measures designed to conserve and moderate water demand may have on the consumer and on the long-range water supply need, and that water quality in the Connecticut River and in Quabbin Reservoir be monitored by responsible Federal and State authorities to insure the safety and purity of the water supplies.

13. The Division Engineer, New England, recommends implementation of the project in accordance with his plan, subject to certain items of local cooperation. The Division Engineer, North Atlantic, concurs.

14. Public notice - The Division Engineer, North Atlantic, issued a public notice stating his recommendations and affording interested parties an opportunity to present additional information to the Board. Careful consideration has been given to the communications received.

Views and Recommendations of the Board of Engineers for Rivers and Harbors.

15. Views.--The Board of Engineers for Rivers and Harbors concurs in general in the views and recommendations of the reporting officers. The improvements are urgently needed and economically justified, and the items of local cooperation, as amended by the Board, are generally appropriate. The reporting officers have estimated the total first cost of the plan at $46,815,000. The Board notes, however, that the first element of the water supply facilities, the modification of the upper pool of the Northfield Mountain pumped storage project for water supply at a cost of $2,000,000, has been completed and believes that Federal participation in water supply facilities, completed prior to project authorization, is not appropriate. Consequently, the $2,000,000 should be deleted and the appropriate estimated total first cost should be $44,815,000.

16. The Board notes that the proposed project is one increment of a long-range solution of the water needs of the southeastern New England region. The Northfield Mountain water supply project, along with the Millers River project, would provide additional water to meet the 1990 demands of the present MDC service area and other municipalities which require additional short-range supply and do not have access to feasible water supply sources. Additional water supplies will be needed to meet the 1990 water demands of the remaining region. Furthermore, if continued regional growth and development are considered desirable, additional measures will be required to satisfy the long-range water demands of the whole region.

17. The Board is convinced that the Northfield Mountain project fulfills an urgent regional water supply need and does so at least cost. It is also convinced that implementation of this project will not preclude the development of alternative projects in the future, and that it offers maximum flexibility for accommodating future conditions. Furthermore, supplemental information furnished by the reporting officers indicates that adequate consideration was given to comprehensive regional water needs and supply systems to support the conclusion that the Northfield Mountain project would be compatible with any of the more desirable long-range regional plans. Therefore, the Board believes that construction of the Northfield Mountain project is a logical next step in meeting the region's increasing water supply needs. The Board notes, however, that a definite regional plan has not been selected and believes that a future report, in response to Title I of Public Law 89-298, should further and more explicitly address potential regional plans, short- and long-range, with recommendations for the appropriate Federal role for continued planning and implementation to meet the region's water supply needs.

18. The Board reviewed the methodology used by the reporting officers for estimating water supply benefits, which is based on estimated revenue losses to municipalities marketing water and losses to citizens and industries due to water shortages and curtailed use. While it found that this approach reinforces the support for the improvements, the Board believes that the national economic efficiency requirement is best satisfied because the proposed project is a least costly means of providing the needed increment of water supply to the region.

19. The Board is also satisfied that there is sufficient Federal interest in this project, pursuant to Title I, Public Law 89-298, to warrant Federal participation, based on the following reasons provided by the reporting officers:

a. The project would service a metropolitan region;

b. The project would have interregional and interstate impacts;

c. The project involves regional equity issues;

d. The project involves resolution of interbasin water transfer issues; and

e. The project would expand the regional water service area and improve efficiency of resource utilization.

20. The Board concurs in the reporting officers' recommendation that the repayment provisions of the Water Supply Act of 1958, form the most appropriate basis for deriving the degree of Federal financial participation for the Northfield Mountain water supply project. The

Board believes, however, that authorization of the proposed project with the recommended Federal participation should not establish a precedent for cost sharing in other projects formulated in response to the NEWS legislation.

21. The Board recognizes that the water quality of Quabbin Reservoir, the major water storage facility in the MDC system, is excellent while the quality of the proposed diversion flows from the Connecticut River is lesser and that there are some uncertainties regarding the degree of project impacts on the ecology of the existing system. The Board, also, recognizes similar uncertainties, but of lesser significance, regarding the impacts of the proposed diversion on the Connecticut River ecosystem. It is the Board's view, therefore that, in addition to the water quality monitoring recommended by the reporting officers, other studies should be conducted to more precisely define the scope of the water quality problems, the project's ecological effects on the Connecticut River and Quabbin Reservoir, and to determine any project design modifications that are necessary.

22. The Board notes that the usefulness of the proposed project depends, physically and economically, on the operation of the Northfield Mountain pumped storage hydroelectric facility. It, therefore, believes that local interests should provide assurances that these facilities will continue in operation, to the extent needed to fulfill the proposed project functions.

23. The Board believes that the reporting officers have adequately considered the impacts of the proposed diversion on the supply and receiving areas, and on upstream and downstream interests and have recommended an equitable solution to the urgent water supply problem of the region. The diverted flows from the Connecticut River would occur only during high river stages and would not interfere with flow requirements in the Connecticut River. Thus, the proposed project would not constitute a substantial threat to the State of Connecticut. The Board is convinced, furthermore, that resolution of any jurisdictional claims associated with the proposed project can be approached best by requiring local interests to hold and save the United States free from water rights claims, rather than by stipulating specific actions to the involved jurisdictions which would infringe upon their sovereign prerogatives. The Board notes, however, that long-term water supply needs for southeastern New England may place further demands on the Connecticut River system, and understands the concern of the State of Connecticut. The Board, therefore, believes that it would be in the public interest, as well as in the best interest of all parties concerned, for the States of Massachusetts and Connecticut to enter into an agreement regarding the management and allocation of the waters of the lower Connecticut River.

24. The Board has carefully considered the environmental effects, including those discussed in the Revised Draft Environmental Impact Statement dated December 1973, and it concludes that the adverse effects on the environment will be minor and that the positive effects of the project will be significantly greater. The Board also considered the effects on regional development and social well-being, as required by the Principles and Standards for Planning Water and Related Land Resources established by the Water Resources Council, and it believes that the proposed improvements would provide a significant contribution to the regional economy and improvement of social well-being.

25. Recommendations.--Accordingly, the Board recommends Federal participation in the design and construction of the water supply diversion facilities of the Northfield Mountain water supply project, generally in accordance with the plan of the Division Engineer, New England, and with such modifications thereof as in the discretion of the Chief of Engineers may be advisable, at a presently estimated cost to the United States of $44,815,000: Provided that, prior to the commencement of construction, non-Federal interests will agree to:

a. Reimburse the United States the entire amount of the total cost, including interest during construction, such reimbursement shall be repaid in accordance with the repayment provisions of the Water Supply Act of 1958, as amended;

b. Hold and save the United States free from damages including damages from water rights claims, due to the construction and operation of the project, not including damages due to the fault or negligence of the United States or its contractors;

c. Provide assurances that those functions of the Northfield Mountain pumped storage hydroelectric facility which are necessary for proper operating of the proposed project will be provided throughout the life of the project;

d. Operate and maintain all features of the project after completion; and

e. Insure that communities within the potential Metropolitan District Commission service area, and generally as designated by the Division Engineer as requiring additional short-range water supply, are eligible for admittance to the water supply system operated by the Metropolitan District Commission.

FOR THE BOARD:

D. A. RAYMOND
Major General, USA
Chairman

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INTRODUCTION TO REPORT

1. Introduction

A. Background

The long-term normal rainfall in southeastern New England is about 42 inches per year. This "normal" condition is actually the average of many high and low rainfall years. When rainfall is below average for a period of time, the area experiences a drought. The recent drought of the sixties in southeastern New England caused many water supply systems to re-evaluate the dependable yield which their facilities could produce. In many cases, the new dependable yield was significantly less than previously estimated. In turn, water demands on these same systems have been increasing; therefore, additional supplies are necessary.

The drought began in 1961 and continued for seven years, with the severest deficiency occurring in 1965. During this period, an extreme drought condition existed in the northern half of New Jersey, northeast Pennsylvania, southeastern New York, all of Vermont and New Hampshire, parts of southern Maine, and the western half of Massachusetts. Within the region, the heavily industrialized and urbanized area extending from Boston to Washington was most severely affected.

The severity of the situation was caused by a combination of two factors--a severe hydrologic adversity and the centering of the drought on the most densely populated region of the United States. In addition, many water supplies had been developed on the smaller upland prestine streams rather than on larger rivers with lower quality, but having a more dependable flow. Thus, the many cities and towns which relied upon upland sources were particularly hard hit by the drought.

At the height of the drought, major metropolitan regions surrounding Philadelphia and New York City faced mandatory restrictions in water use. Within Massachusetts, 85 cities and towns, including the two million customers of the Metropolitan District Commission, were asked to institute voluntary water rationing programs. Normal water use practices, such as lawn sprinkling and car washing, were sharply curtailed. In 23 Massachusetts' communities, emergency sources of water, sanctioned by the Public Health Department for temporary use only, were necessary to meet water needs.

In addition to affecting the water supply of almost 14 million people, the drought also had a severe impact on the environment. Low stream flow intensified pollution problems, affecting water quality and fish and wildlife. Algae blooms caused problems of taste and odor in water supplies and interfered with recreational use of lakes and reservoirs.

The prolonged sixties' drought thus caused extensive hardships on man and his environment. Fortunately, the years immediately prior to the advent of the drought were abnormally "wet" years. These "wet" years allowed many of the region's supply reservoirs to enter the drought period in a filled condition, precluding even more severe water use restrictions. There is no assurance, however, that the next drought, whenever it may occur, will be preceded by reservoir and aquifer filling "wet" years.

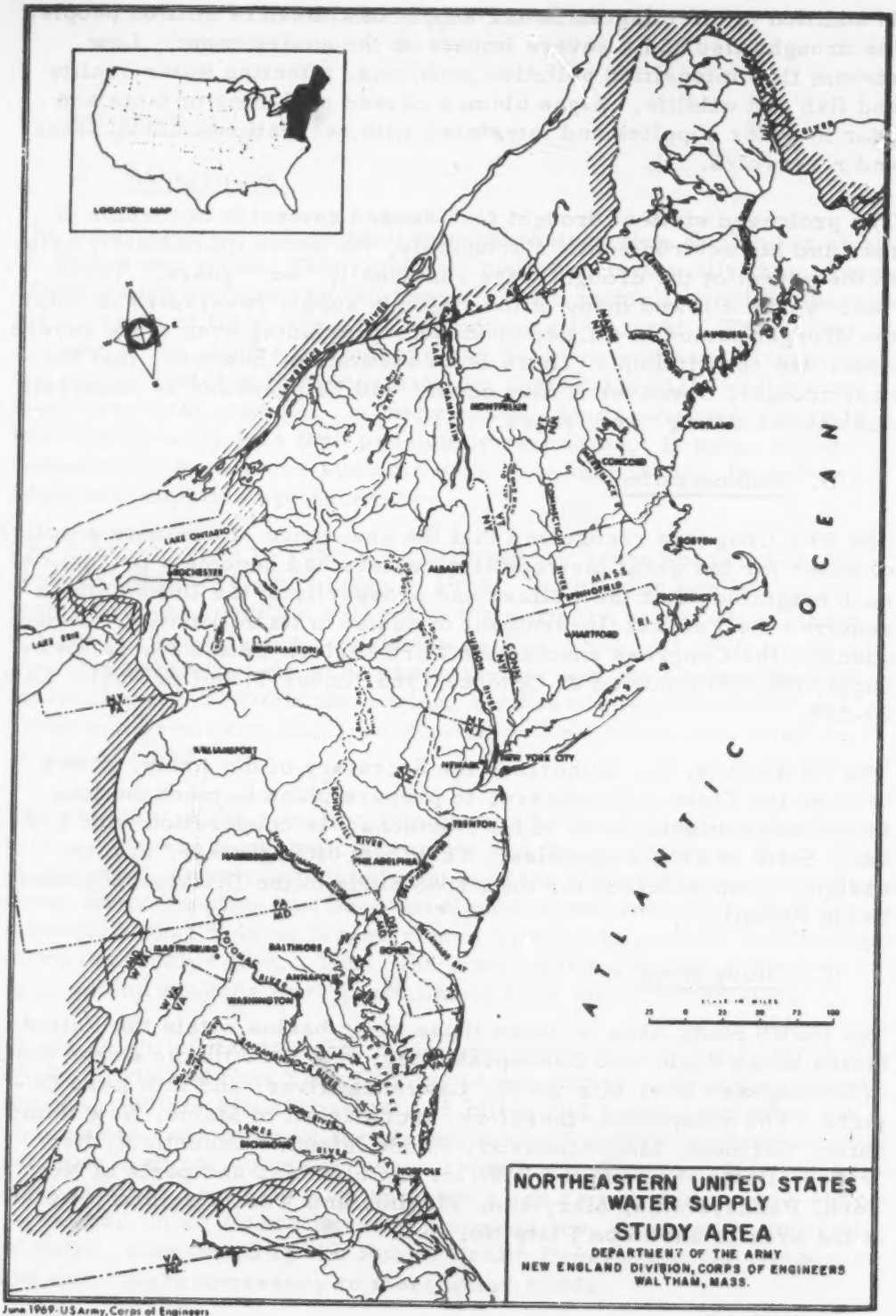
B. Authorization

The 89th Congress recognized that the assurance of adequate supplies of water for the great metropolitan centers had become a problem of such magnitude that the welfare and prosperity of the United States required the Federal Government to assist in its resolution. Consequently, the Congress enacted the Northeastern United States Water Supply (NEWS) Study on 27 October 1965, under Title I of Public Law 89-298.

The NEWS Study Act authorized the Secretary of the Army, acting through the Chief of Engineers, to prepare plans to meet the long range water supply needs of the Northeast, in cooperation with Federal, State and local agencies. The Chief of Engineers, in turn, assigned responsibility for the NEWS Study to the Division Engineer, North Atlantic.

C. Study Area

The NEWS Study Area includes those river basins within the United States which drain into Chesapeake Bay, into the Atlantic Ocean north of Chesapeake Bay, into the St. Lawrence River, and into Lake Ontario. The study area, therefore, includes all of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, and the District of Columbia, and parts of New York, Pennsylvania, Maryland, Virginia and West Virginia. A plan of the area is shown on Plate No. S-1.



June 1969-U.S.Army, Corps of Engineers

PLATE S-1

present population is concentrated in the five metropolitan areas of Boston, New York, Philadelphia, Baltimore and Washington; and the region includes twenty of the nation's one hundred largest cities.

Although the area has an average annual precipitation rate of about 40 inches, as compared to the national average of 30 inches, precipitation deficiencies in some parts of the area were up to 50 inches during the October '61 to December '65 period. The area's vulnerability to water shortage is revealed by the fact that some 14 million people, about 28 percent of the population, were restricted to some degree in their use of water during this drought. Although public awareness of the problems of water supply was increased by the drought experience, drought is not the only reason for concern. Available supplies of water of good quality will soon be inadequate, even under normal conditions, to meet the needs of the anticipated population and industrial growth.

D. Objective

The objective of the overall NEWS Study is the preparation of a coordinated general plan for essential water supply development in the Northeast which will recommend to the Congress an active program for Federal, State, local and private organizations. It thus provides a public forum where all vitally concerned with the water supply problems of the area can be heard in developing a plan to resolve one of the many domestic problems now facing the United States.

E. Methods

In achieving its objective, the NEWS Study will present a regional assessment of present and future water supply needs and will present alternatives for their solution. The study effort is being fully coordinated through the various Federal, State, local and private agencies and organizations. Such coordination assures that plans are consistent with, and integral to, other concurrent water resource planned development being formulated. During the study, interim reports will be prepared to deal with critical problems which may be encountered. These reports will contain specific recommendations to the Congress for authorization of major reservoirs, conveyance facilities, or treatment facilities, as may be appropriate. The Northfield Mountain Water Supply Project, described later, is the result of such interim reports.

F. The Urgent Need Areas

The NEWS Study established the premise that areas which will probably exceed the present capabilities of the water supply systems by 1980 are to be considered in the "urgent" category. Under NEWS procedures, projects and regional programs for these "urgent" areas are being developed and made the subject of interim reports which will be submitted to the Congress for authorization. To identify these urgent areas, an initial appraisal, through reconnaissance studies, was made of the present system's capability to satisfy the projected 1980 demands. This appraisal included an evaluation of present system yields, present and projected domestic and industrial consumption, population expansion and economic growth. The appraisal disclosed four critically urgent areas as follows:

1) Eastern Massachusetts and Rhode Island

2) Western Connecticut - Metropolitan New York City and Northern New Jersey

3) South Central Pennsylvania

4) Metropolitan Washington, D. C.

Once these critical areas had been identified, feasibility detail studies were initiated to investigate alternative engineering solutions. The Western Connecticut area, although in the New England Division, because of its geographic proximity to the Metropolitan New York area, was studied in conjunction with that region. The second "urgent" need area within New England, Eastern Massachusetts and Rhode Island (Southeastern New England), was studied by members of the New England Division and is described in the following section. A plan of the Southeastern New England Region is given on Plate No. S-2.

Although, as described earlier, the NEWS Study area includes eastern seaboard states from Maine to Virginia, the subject of this interim report of survey is a project designed to meet a large portion of the critical supply needs within Southeastern New England. The following sections, therefore, focus on those NEWS Studies conducted to date within New England which led to the selection of the Northfield Mountain project as a candidate for Congressional authorization. Similar reports in the other regions of the NEWS Study area are under way, and will be reported upon by the North Atlantic Division, Corps of Engineers.

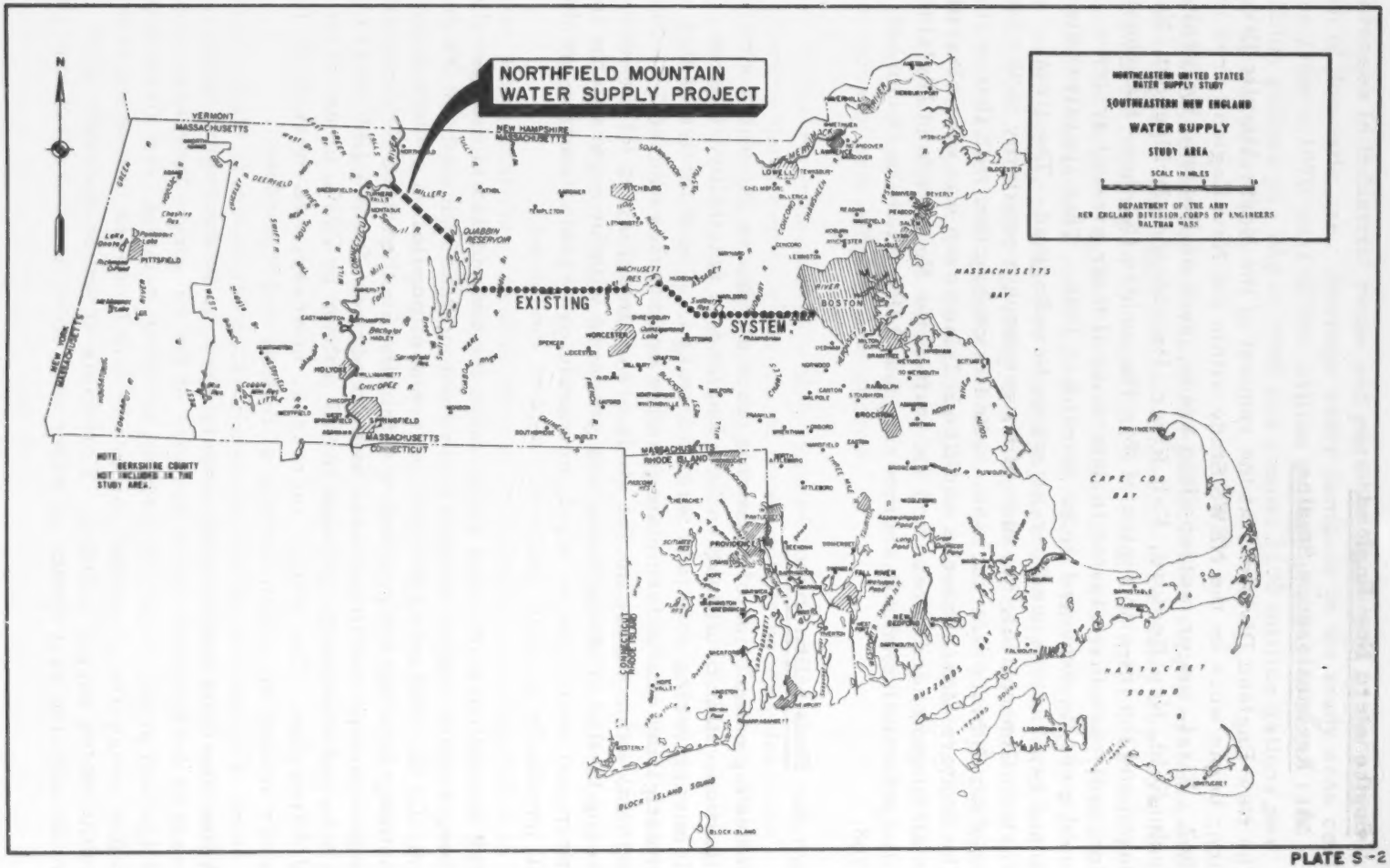

NORTHFIELD MOUNTAIN
WATER SUPPLY PROJECT
EXISTING
SYSTEM
QUABBIN RESERVOIR
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
SOUTHEASTERN NEW ENGLAND
WATER SUPPLY
STUDY AREA
SCALE IN MILES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION CORPS OF ENGINEERS
WALTHAM MASS
NOTE
BERKSHIRE COUNTY
NOT INCLUDED IN THE
STUDY AREA.
VERMONT
MASSACHUSETTS
NEW HAMPSHIRE
MASSACHUSETTS
NEW YORK
MASSACHUSETTS
MASSACHUSETTS
CONNECTICUT
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
RHODE ISLAND
MASSACHUSETTS BAY
CAPE COD BAY
NANTUCKET SOUND
BUZZARDS BAY
BLOCK ISLAND SOUND
BLOCK ISLAND
PITTSFIELD
SPRINGFIELD
WORCESTER
BOSTON
PROVIDENCE
FALL RIVER
NEW BEDFORD
LOWELL
LAWRENCE
HAVERHILL
NEWBURYPORT
GLOUCESTER
SALEM
BEVERLY
PEABODY
LYNN
MALDEN
QUINCY
BROCKTON
TAUNTON
PLYMOUTH
HYANNIS
NANTUCKET

PLATE S-2

2. Southeastern New England

A. Reconnaissance Studies

The New England Division, at the request of the North Atlantic Division, began work on the NEWS Study within the New England area in 1967. First, major metropolitan areas, such as Boston, Worcester, Springfield, New Bedford, Fall River, Providence, Bridgeport, New Haven and the tri-city region of New Hampshire (Nashua - Manchester - Concord) were investigated to determine if their present systems could meet the expected water demand in 1980. This appraisal disclosed two "urgent need" areas within New England. The first, Western Connecticut, because of its geographic proximity to the Metropolitan New York area, was studied in conjunction with that region. The Eastern Massachusetts and Rhode Island area was also classified as an "urgent need" area, and the staff of the New England Division initiated a twelve-month engineering feasibility study in December 1968.

B. Feasibility Study

Following completion of reconnaissance studies on the water supply situation within Southeastern New England, a feasibility study on possible engineering solutions was undertaken. The objective of this investigation was to formulate feasible engineering alternatives for a regional water supply for the study area. In achieving this objective, the evaluation of alternatives was prepared without regard to the institutional restraints -- legal, economic or organizational -- so that all physically feasible projects could be evaluated.

The feasibility study area falls within the boundaries of the so-called "megalopolis" which extends from Boston, Massachusetts to Washington, D. C. Following the general trend of population growth within the megalopolis, the population within the Southeastern New England region is expected to increase at a steady rate from a 1970 total of 6.5 to 7.8 million in 2000 and to 9.7 million by 2020, or an increase of 49 percent. The largest increases, however, are most likely to occur around the urban centers of Boston and Providence.

Water use from public water supply systems in the region has increased dramatically since the turn of the century. Increases in population and productivity, movement to urban regions, and rises in per capita usage are important factors in this increase in demand from public water supply utilities. Forecasts of future demands were made utilizing past trends of water use, modified to reflect expected

increases in industrial reuse and possible decreases in the proportion of domestic use. Average water demands in the study area could rise from a 1970 total of 850 million gallons per day to about 1300 million gallons per day in 1990 and almost 2100 million gallons per day by the year 2020.

At present, there are a total of 369 public water supply systems within the region. The aggregate developed yield or water available for consumers from these systems totals about 1,000 million gallons per day. The largest regional system within the area is the Metropolitan District Commission system, which services either wholly or partially the water supply needs of 41 municipalities with a population of about 2,000,000. The average daily consumption of these communities in 1971 was 322 million gallons per day, while the safe yield of the system is estimated to be 300 million gallons per day. If this system and others in the region are to provide the anticipated demand without major modifications of consumer water use habits, then large quantities of new supplies are needed.

Nine major river basins were investigated to determine their potential in meeting the previously described water supply needs. Included were the Connecticut, Merrimack, Ipswich, North, Taunton, Pawtuxet, Blackstone, Pawcatuck, and Thames River Basins. A plan showing the location of the basins is given on Plate No. S-3. Also, ground water resources were assessed for regional use and for local potential development. Other techniques such as desalination, waste water reuse, and weather modification were evaluated for their role in augmenting regional water supply systems.

From a regional view, available water resources were identified in sufficient quantities to meet forecast water demands even beyond the year 2020. Potential supply problems within the region thus are not occasioned by a scarcity of resources, but rather by the lack of facilities which develop the resource. Water supply problems within the region arise from shortage of developed facilities, shortage of suitable sites for new facilities, and competing alternative uses for land and water resources.

Twenty-eight regional projects, shown on Tables S-1 and S-2, were described in the feasibility report as possible engineering solutions.

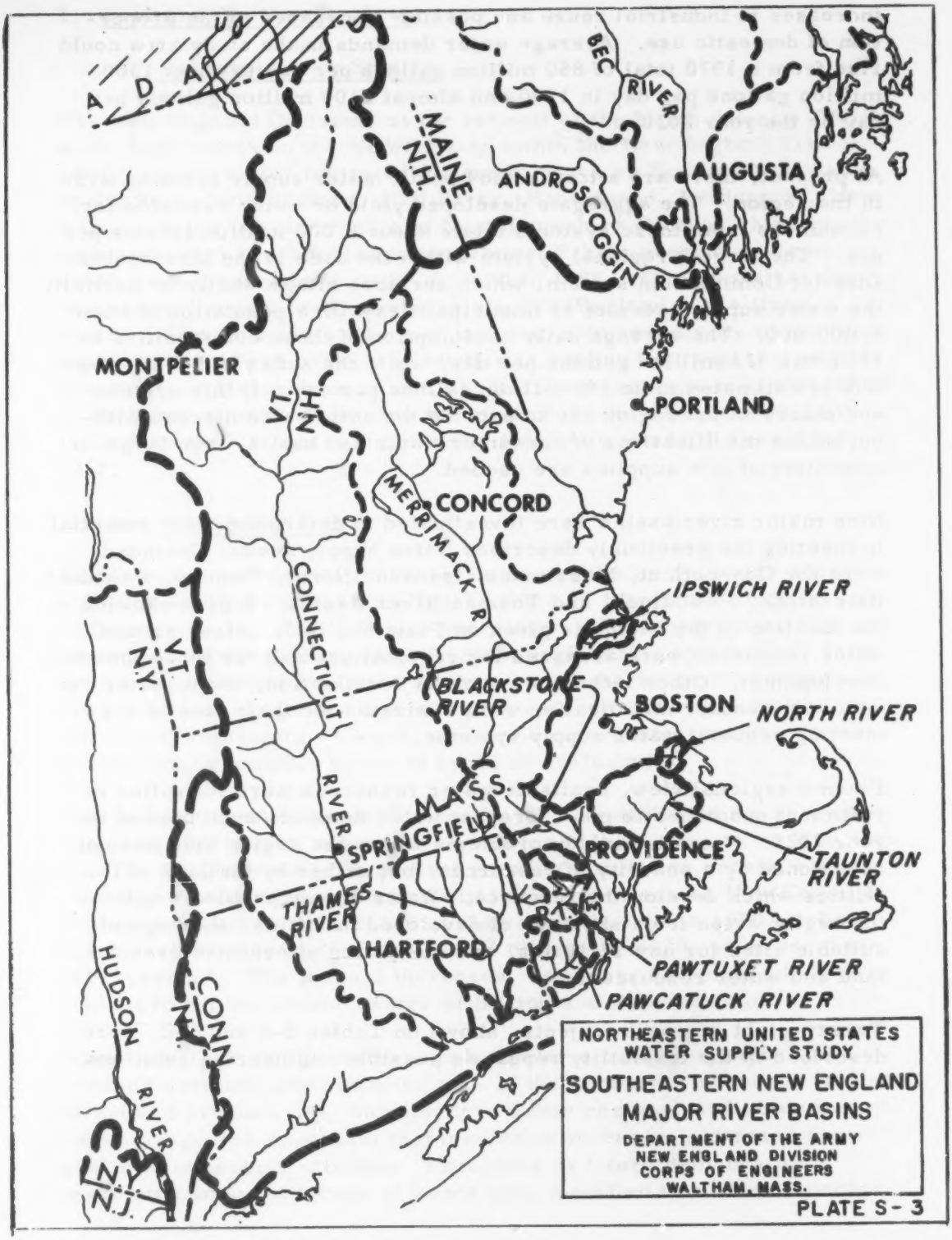

CANADA
MAINE
N.H.
VT.
N.H.
VT.
N.Y.
CONN.
N.Y.
N.J.
BEC RIVER
ANDROSCOGGIN R.
AUGUSTA
PORTLAND
MONTPELIER
CONCORD
MERRIMACK R.
CONNECTICUT RIVER
IPSWICH RIVER
BLACKSTONE RIVER
BOSTON
NORTH RIVER
MASS.
SPRINGFIELD
PROVIDENCE
TAUNTON RIVER
THAMES RIVER
R.I.
HARTFORD
PAWTUXET RIVER
PAWCATUCK RIVER
HUDSON RIVER
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
SOUTHEASTERN NEW ENGLAND
MAJOR RIVER BASINS
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
PLATE S-3

TABLE S-1

POTENTIAL PROJECTS REPORTED UPON IN FEASIBILITY REPORT
TO MEET 1990 SUPPLY NEEDS

Basin	Project Name	Yield (mgd)	Method of Development	Construction [1] Cost (1×10^6 $)	Annual Cost [1] ($1 mg)
Connecticut River	Tully	55	High Flow Withdrawal	25.3	93
	Northfield Mountain	125	High Flow Withdrawal	37.9	91
	Hadley	125	High Flow Withdrawal	60.5	141
	W. Deerfield	125	High Flow Withdrawal	74.6	154
Merrimack River	Merrimack - No. Middlesex	35	High Flow Withdrawal	18.1	131
	Merrimack - No. Middlesex - Essex	50	High Flow Withdrawal	36.4	165
	Merrimack - E. Massachusetts	230	High Flow Withdrawal	146.5	141
Ipswich River	Ipswich River Reservoirs	15	High Flow Withdrawals & Storage	15.8	224
North River	North River Reservoir	25	Storage	18.1	151
Taunton River	Lakeville Ponds	25	High Flow Withdrawal	45.7	288
	Copicut Reservoir	25	High Flow Withdrawal & Storage	64.0	403
Pawtuxet River	Big River Reservoir	29	Storage	45.9	322
Massachusetts Ground Water	Plymouth County Ground Water - No. Plymouth	12	Withdrawal from Ground Water Aquifer	20.2	423
	Plymouth County Ground Water - Bristol County	28	Withdrawal from Ground Water Aquifer	48.9	378

[1] 1969 Feasibility Study Costs Updated to 1972 Price Level.

TABLE S-2

POTENTIAL PROJECTS REPORTED UPON IN FEASIBILITY REPORT TO MEET 2020 SUPPLY NEEDS

Basin	Project Name	Yield (mgd)	Method of Development	Construction[1] Cost (1×10^6 $)	Annual Cost[1] ($1 mg)
Connecticut River	Hadley - A	500	High Flow Withdrawal	595 (495)[2]	253 (219)[2]
	Hadley - B	550	High Flow Withdrawal	615 (523)[2]	237 (213)[2]
	Knightville Reservoir	20	Storage	35.4	218
	South Hadley	40	Direct Withdrawal	19.7	141
Merrimack River	Lowell - A	500	Direct Withdrawal	452 (398)[2]	191 (176)[2]
	Lowell - B	550	Direct Withdrawal	468 (427)[2]	178 (168)[2]
Combined Connecticut & Merrimack Rivers	Lowell - So. Hadley - A	500	Direct & High Flow Withdrawal	465 (421)[2]	200 (186)[2]
	Lowell - So. Hadley - B	550	Direct & High Flow Withdrawal	489 (445)[2]	194 (183)[2]
Taunton River	Taunton River Estuary Dam	97	Storage and Direct Withdrawal	80.2	183
Pawtuxet River	Flat River Reservoir	13	High Flow Withdrawal	9.7	203
Thames River	Moosup River Reservoir	20	Storage and High Flow Withdrawal	23.1	290
Pawcatuck River	Wood River Reservoir	30	Storage and High Flow Withdrawal	30.0	247
Blackstone River	Nipmuc and Tarkiln Reservoir	14	Storage and High Flow Withdrawal	23.0	302
Pawcatuck Ground Water	So. Central Rhode Island	11	Withdrawal from Ground Water Aquifer	9.4	236

[1] 1969 Feasibility Study Costs Updated to 1972 Price Level.

[2] Based on Earlier (1990) Merrimack River Development.

C. Events Leading to Project Selection

The feasibility report on possible engineering alternatives for meeting future water supply needs within southeastern New England was completed in November 1969. Draft copies of the report were then distributed for comments by other agencies with responsibility in water resource planning and implementation.

Other Federal Agencies receiving review drafts included the Departments of: Interior; Agriculture; Health, Education and Welfare; Housing and Urban Development; and Commerce.

Draft copies were also sent to the six New England State Coordinators whose offices had been designated by the respective State Governors as state clearing houses for the NEWS Study. These state coordinators in turn distributed the reports to State Agencies which could provide input as review comments.

Established Regional Planning Agencies in the New England States received review copies and were asked to forward their comments through the State Coordinators.

Following the receipt of comments from the various agencies, a meeting was scheduled by the North Atlantic Division in Boston, Massachusetts, for 7 May 1970. The objectives of this meeting were as follows:

(1) To present and discuss the various alternative water supply projects reported upon in the feasibility study. Included in this element was a description of an alternative technique for diverting excess flows from the Merrimack River without upstream augmentation reservoirs and the need for implementing a pollution abatement program to insure adequate water quality.

(2) To discuss the need for and scope of an environmental impact study of the various engineering alternatives.

(3) To select one or more of the engineering alternatives for which more detailed studies in engineering, economic evaluation, environmental and social impact might be undertaken as NEWS Studies.

In a broader sense, the objective was to assure adequate supplies of water for the region in the most beneficial manner possible; i.e., with the optimum overall economic, environmental, and social impact

on the region and the country as a whole. Flexibility, reliability and timeliness are some of the selection criteria used to maximize these components. Political and institutional tendencies and existing laws or statutes act, with varying degrees of rigidity, as constraints in project selection.

Attendees at the meeting varied from Federal and State Agencies to private organizations such as the Audubon Society. A complete list of organizations in attendance is as follows:

Massachusetts
- Metropolitan District Commission
- Division of Water Resources
- Division of Fish and Game
- Division of Marine Fisheries
- Water Resources Commission
- Department of Public Health

Connecticut
- Water Resources Commission

Rhode Island
- Water Resources Board

New Hampshire
- Water Supply and Pollution Control Commission
- Water Resources Board

New England River Basins Commission

United States Department of the Interior

United States Public Health Service

Office, Secretary of the Army

United States Army, Corps of Engineers
- Office, Chief of Engineers
- North Atlantic Division
- New England Division

New England Natural Resources Center

Massachusetts Audubon Society

City of Boston

Anderson Nichols and Company

Union of Concerned Scientists

At the outset of the meeting, a Corps of Engineers representative stated that the NEWS Study was prepared to undertake detailed investigations on potential water supply projects in southeastern New England. These projects, if authorized and constructed, would then aid in meeting the short range "urgent" water supply needs of the region.

The Corps of Engineers spokesman noted, however, that available funding and manpower did not allow for detailed analysis of each alternative project. Therefore, the various agencies and organizations present were requested to state their views on those projects for which immediate detailed studies might be undertaken. By this manner, it was felt that the Corps of Engineers could then proceed with those projects which would efficiently utilize available funds to study projects with maximum relief to the region.

Discussion at the meeting ranged from engineering and environmental considerations of the various possible alternatives to concern with socio-economic impacts. At the end of the meeting, consensus on a number of detailed studies, which should be initiated immediately, was reached. These projects selected from the many potential alternatives described in the feasibility report are as follows:

(1) The Corps of Engineers should proceed with detailed studies on the development of Tully Reservoir.

(2) The Corps of Engineers should consider the Northfield Mountain Water Supply Project as a very viable element in any regional water supply plan for southeastern New England. Accordingly, the Corps should initiate detailed studies on this project and these studies should be designed to complement those already under way or planned by the Metropolitan District Commission.

(3) The Corps of Engineers should conduct studies on the possibility of using the Merrimack as a regional source of water supply and concomitant studies on requirements for improving its quality.

(4) The Corps should conduct a broad environmental impact study of all alternatives proposed for southeastern New England.

(5) The Corps should conduct a detailed study specifically directed at determining the effects of upstream diversion on the estuaries of both the Merrimack and Connecticut Rivers.

(6) The Corps should explore the possibilities of advanced site acquisition, beginning in the State of Rhode Island.

Utilizing the selected work items as a basis, the NEWS work program for southeastern New England was constructed. One of the projects selected at the May 1970 meeting, namely, the Northfield Mountain Water Supply Project, is the subject of this report.

D. Other Areas Requiring Early Attention

The projects selected for detailed studies, as described in the previous section, would provide a large input towards supplying short range water needs in southeastern New England. Even if the projects undergoing detailed investigations, such as the Northfield Mountain Water Supply Project, were constructed, other areas within the region will require early augmentation of available supplies.

As illustrated in the graph displayed on Plate No. S-4, implementation of the Northfield Mountain Project and its companion report, Millers River, projects would provide 148 million gallons per day of additional supply.

Total forecast short range additional (1990) water needs, however, within southeastern New England are estimated to be about 316 million gallons per day, while additional long range (2020) needs may total about 1,084 million gallons per day. Thus, although the Northfield Mountain and its completion report (i.e. Millers River) will contribute significantly toward meeting both short and long range needs, other projects will be necessary.

As a means of meeting a portion of these other need areas, the NEWS Study is presently preparing an Interim Report of Survey on the potential development of the Merrimack River as a supply source. The possibility of such development was an element agreed upon at the May 1970 meeting as requiring detailed analysis.

Since present water quality in the Merrimack River is poor, an investigation[1] of alternatives for managing wastewater in the basin was the

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[1] The Merrimack: Designs for a Clean River: Alternatives for Managing Wastewater in the Merrimack River Basin, September 1971, prepared by Northeastern United States Water Supply Study.

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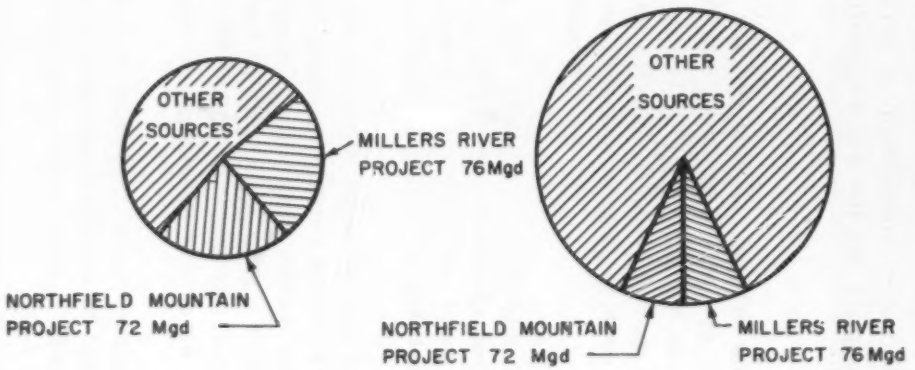

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

ADDITIONAL WATER SUPPLY NEEDS
SOUTHEASTERN NEW ENGLAND AREA

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE S-4

first study undertaken by the NEWS Study. A follow-up Interim Report of Survey on possible wastewater treatment plants in the Massachusetts portion of the basin is now being conducted.

The completion of the water supply and wastewater studies presently under way will identify the potential which the Merrimack River Basin has in meeting water supply needs not met by the Northfield Mountain and Millers River Basin Water Supply Projects.

Other areas slated for detailed investigation include the Providence, Rhode Island Metropolitan Region; the Ipswich River Basin; northern Plymouth County and southeastern Massachusetts. Completion of all these detailed studies and implementation of recommended projects would insure adequate supply for the entire southeastern New England region.

3. Summary of Selected Project -- Northfield Mountain Water Supply Project

A. Water Supply Setting

As recognized in the NEWS Legislation, natural departures from normal precipitation and runoff conditions can have regional impacts on the social well-being of a large segment of the nation's population.

The sixties' drought, which began in 1961 when precipitation and water levels fell below normal, ultimately directly affected the water use patterns of more than 20 million people. In 1965 alone, drought related water shortages and associated problems were severe enough to warrant emergency actions by local, state and Federal agencies. Within Massachusetts, 85 cities and towns imposed restrictions on water use.

Historically, within the study area, public water supply has been furnished through municipal level utilities. In 1965, there was a total of 369 public water systems servicing water needs of the region. Population served by these suppliers varies from less than one hundred to more than two million for the largest system, the Metropolitan District Commission (Boston).

During and following the drought, a number of communities conducted engineering studies to determine methods for augmenting their existing supplies. In some cases, new supplies have been developed by municipalities which would allow them to meet supply needs.

As a supplement to the actions taken by the local and regional supply agencies, regional planning agencies have been active in evaluating the various systems' capability to meet future supply requirements. Investigations conducted by the local water utilities, the regional planning agencies and the NEWS Study all indicate that additional supplies are necessary if the short range needs are to be met.

In this Interim Report of Survey, three[1] major groups of communities which could be serviced by the addition of the Northfield Mountain Water Supply Project have been identified. These are:

(1) Forty-one communities which are presently serviced by the Metropolitan District Commission (Boston), the largest regional system in the study area.

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[1] Background data contained in Appendix B - Future Population and Water Demand Studies.

(2) Twenty-four communities which the various local and regional planning agency studies identified as having no reported future source of supply except connection to the MDC system.

(3) Sixty-six communities which have reported local resource potential to meet short range (1990) needs. As an alternative to further local resource development, these communities could also attempt to join the existing regional system.

The municipalities included in the first two categories above are considered for purposes of this report to be the probable 1990 service area which would utilize the supply made available by the Northfield Mountain Project. Existing and proposed dependable yield of these cities and towns is estimated to be about 383 million gallons per day. Total 1990 water supply requirements on the other hand are estimated to be about 524 mgd, thus forecast water deficits could total about 141 mgd.

The Northfield Mountain Water Supply Project would add an estimated 76 mgd to the available supplies. Implementation of the Northfield Mountain Project, therefore, would provide about half of the estimated 1990 supply deficit of the serviced communities. In order to meet the total deficit, another source of supply must be developed. The Millers River Basin in north-central Massachusetts is a candidate for development for this needed supply and is the subject of a separate report.

The sixty-six communities listed in category (3) as possessing sufficient local resource potential to meet 1990 needs were considered for purposes of this report as a "possible" service area. The focus of present planning by these municipalities, however, appears directed toward development of these local resources rather than connection to the existing regional system. Therefore, it is not considered likely that these communities will join the system in the short range.

In summary, certain groups of communities (particularly those outside Metropolitan Boston) can satisfy their present and projected 1990 needs without relying directly on the MDC. However, they cannot do so unless the MDC supplies certain key communities. It, therefore, becomes apparent that any concept of regional supply for the eastern Massachusetts - Rhode Island Study Area depends on firming up the existing regional system i.e., the MDC. This is the specific problem addressed by the present survey report.

Also by 1990, many eastern Massachusetts communities not served by the MDC will collectively require water in addition to that available in their immediate watersheds. The development of institutions and physical systems to cope with this regional problem is critical. By 2020, the MDC will also require additional water from a large regional source. These two problems are the subjects of on-going studies.

B. Description of the Project

Authorization for construction of the diversion facilities from Northfield Mountain to Quabbin Reservoir has been granted to the Metropolitan District Commission by the Massachusetts State Legislature. Recognizing this fact, the representatives of the Federal, State and local agencies and interests at the May 1970 meeting recommended that the Corps of Engineers investigate the project as a very viable element in any regional water supply plan for Southeastern New England. It was further recommended that the NEWS studies be designed to complement those under way or planned by the Metropolitan District Commission.

The Northfield Mountain Diversion project would use a high flow skimming technique; that is, flow would be diverted during high flow periods, principally during spring run-off periods. Water would be diverted from the Connecticut River through the Northfield Mountain pumped storage hydroelectric facility located in Northfield and Erving, Massachusetts. As a means of control, diversions would not occur if flow in the Connecticut River at Montague City U.S. Geological Survey gaging station is less than 17,000[1] cubic feet per second or about 11,000 million gallons per day.

The pumped storage project for electricity generation consists of a high level storage reservoir on Northfield Mountain, underground pump-turbine facilities and low level storage in the Turners Falls pool. The high level reservoir consists of a system of dams and spillways to provide 17,000 acre-feet of storage, about 800 feet above the Turners Falls pool on the Connecticut River.

In order to provide the water supply diversion volume, the electric utility would pump an additional 375 million gallons each day that control flows in the Connecticut River would allow. The additional yield which could be made available by this plan would be 84 million gallons

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[1] This control flow is specified in the current Massachusetts State Legislation regarding the Northfield Mountain Project.

per day on a long term average annual basis. Because of operational considerations, however, the yield estimated to be made available to Quabbin Reservoir is about 72 million gallons per day.

In order to incorporate the water supply diversion into the Northfield Mountain Project, three modifications to the pumped storage facilities are necessary. These are:

(1) Raising the upper reservoir located on Northfield Mountain about 4 feet to provide about 50,000,000 cubic feet of additional storage capacity.

(2) Provision of headworks at the upper reservoir for the diversion aqueduct to Quabbin Reservoir.

(3) About 9.8 miles of connecting aqueduct and outlet facilities at Quabbin Reservoir.

The first two items necessary for water supply diversion have been essentially completely constructed at the upper reservoir on Northfield Mountain by the electric utility construction forces.

The third item necessary for water supply diversion is presently in preliminary design stages by engineers at the MDC. At present, plans indicate water would be diverted from the upper reservoir through an eight-foot diameter steel pipe constructed in the east dike of the Northfield Mountain upper reservoir. Water would be withdrawn at an average rate of 375 million gallons per day and delivered to an intake shaft of the Northfield - Quabbin tunnel aqueduct.

The intake down shaft would be a scroll type configuration with a diameter of 16 to 18 feet. The aqueduct itself would be a 10-foot finished diameter tunnel with a reinforced concrete liner.

Cost estimates for the water supply facilities including the raising of the upper reservoir at Northfield Mountain, intake works, connecting tunnel aqueduct to Quabbin Reservoir and outlet works would total about 40 million dollars.

1) Water Treatment Required

The quality of the Connecticut River varies depending upon upstream municipal and industrial waste discharges, river flow, velocity, time

of year and other considerations. The river's water quality in the vicinity of the Northfield intake has been tested by a number of Federal and State agencies. In addition, testing of the water quality, reported upon in Appendix D, was conducted as part of this study.

Upon analysis of available data, it was concluded that no water treatment is necessary prior to the diversion of Connecticut River water to Quabbin Reservoir. This conclusion is based on the assumption that proper water quality monitoring of Connecticut River water would be performed in the interim years during construction as well as during actual diversion periods and that planned pollution abatement plants will be constructed and in operation.

To safeguard Quabbin itself, the option of including a dual outlet system has been considered. To provide for this future flexibility, if needed, the Northfield-Quabbin aqueduct would include a tunnel stub heading toward the West Branch of the reservoir. If needed in the future, because of water quality considerations, the remaining portion of this tunnel could be constructed.

2) Waste Treatment Required

Water quality investigations indicate that the Connecticut River can be used as a supply source after reservoir storage detention and adequate measures for disinfection. If pollution loads upstream from the Northfield intake continue unchecked, however, there is no assurance that the quality will remain satisfactory.

The Environmental Protection Agency, in cooperation with the New Hampshire Water Supply and Pollution Control Agency and the Vermont Division of Water Supply and Pollution Control, has established an implementation schedule for abatement of pollution discharges upstream from the diversion intake at Northfield. This implementation schedule [1] calls for secondary waste treatment facilities to be constructed and in operation by 1976. Adherence to this established schedule is vital to the quality of the Connecticut River water which is to be diverted for water supply purposes. If the schedule is not adhered to, the potential for increased pollution loads hindering the use of the river as a water supply source is a strong possibility.

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[1] In addition, the Water Quality Act of 1972 calls for zero pollution discharge by 1985.

C. Project Impact Analysis

The evaluation of the project's impacts was accomplished using the three account system developed by the Water Resources Council. Under the Council's proposed guidelines, the overall purpose of the project is measured with regard to enhancing National Economic Development. Environmental Quality and Regional Development.

In order to assess the project's impacts, studies on engineering, socio-economic[2] and environmental[3] considerations were examined. The objectives were to determine and evaluate the potential beneficial contributions as well as neutral or adverse effects which the projects may have. Since the project under consideration involved transfer of a resource through inter-basin diversion, impacts were investigated for both source and receiver areas.

Impacts are quantified and translated into dollar values where possible. In those cases where impacts are not quantifiable, the effects of the project are discussed such that the reader will be aware of all the ramifications of implementing the project.

In general, tangible impacts felt by source areas will be related principally to limited land taking and subsequent construction activity.

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[2] Background data contained in Appendix F.

[3] Background data contained in Appendices D and E.

Apart from the few physical structures proposed, the natural character of the area will remain unchanged. The bulk of surface work will come in remote wooded areas with a minimum of disruption to local traffic patterns. Evidence of the tunneling to Quabbin from Northfield will be seen primarily as access shafts in three or four locations and spoil disposal sites which have not yet finally identified.

From an economic standpoint, changes relate chiefly to the job openings stimulated by construction. Two qualifying points must be made, though, to establish a proper perspective on a labor influx. First, the project will require about 500 men, a comparatively small number with respect to the much larger work forces assembled at the Vermont Yankee Nuclear power generating plant and the Northfield Mountain pumped storage project now under construction. Experience indicates that even if this number were to be larger than the Vernon case, it is unlikely that the supplier area would suffer any adverse effects, e.g., school over-crowding, housing shortages, transportation snarls, etc. As a second mute on impacts, it may be that workers at the Vernon nuclear and Northfield hydroelectric project will move on to the water supply project.

Apart from relatively small economic impacts, social impacts relating to supplier area residents' perceptions of equity are particularly significant. The source area feels a kind of moral outrage at being "forced to give up our water." The statements of their spokesmen sound a sense of frustration with the present system of water allocation decision-making. The personification of this attitude was observed at all of the NEWS Public Meetings held within the Connecticut River Basin. At these Public Meetings, both this report's project and a companion project in the Millers River Basin (the subject of a separate report) came under fire by local opposition. However, of the two projects, the Millers River Basin plan drew the heaviest antagonism.

On the other hand, development of the Northfield Mountain water supply project would insure protection from water shortages and associated social and economic losses. Estimates of economic losses prevented by project implementation when compared to project costs indicate the project to be economically efficient. With respect to the Regional Development objective, the project would provide a benefit/cost ratio of 1.2 under average runoff conditions; and under a hypothetical drought situation, this ratio was estimated to be 1.9. In the National Economic Development account, concrete losses prevented by implementation compared to project costs yields a benefit/cost ratio of 1.1 under normal and 1.7 under drought runoff conditions.

If the project were not implemented, social costs as well as economic costs could be expected in the receiver communities. Social impacts in the receiver area are principally "shadow costs" of concrete losses generated by water shortage. As municipal efforts turn to finding new sources, building bans to hold the line on new demand are a likely eventuality. Second-order effects of expenditures on water searching manifest themselves as slowed school building programs, poorer municipal services (especially fire protection) and a general malaise in the development plans of the subject town. In many ways, these effects are reflected in attitudes about the desirability of the town as a place to live and work. The net result is stagnating growth, hostility toward the communities which snare the industries unable to locate in a water-deprived town, and a growing dependence on MDC admission as the ultimate solution to water shortage.

From the outset, this study made a determined effort to evaluate the impact which the Northfield Mountain water supply diversion might have on Environmental Quality. An analysis was made regarding impact on the Connecticut River Estuary, on the Connecticut River downstream from the point of diversion, and on the environment of the receiving water storage reservoir.

In general, as described in the main report and fully in Appendices D and E, impact caused by the diversion on the estuary and Connecticut River itself is expected to be minimal. The primary reason for this lack of environmental impact is the relatively small amount of water when compared to river flow which would be diverted.

In evaluating environmental impact on Quabbin and Wachusett Reservoirs, field and laboratory data included about 100 parameters, including chemical, physical, biological and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information and pollution abatement plans were considered and evaluated.

Central to the evaluation was a qualitative model of reservoir dynamics. If water of lower quality such as that in the Connecticut River is introduced to a high quality supply like Quabbin Reservoir, there will most likely be a loss in the reservoir system. A number of parameters including turbidity, chemical oxygen demand, dissolved oxygen and nutrients such as nitrogen and phosphorous received close attention.

Within the receiving water body at Quabbin, the diverted flow may have impacts, but these possible impacts depend to a large degree on what engineering steps are taken prior to the actual diversion. For example, the present waste loads in the river may provide opportunities for

algae growth or oxygen depletion. However, if current pollution abatement schedules are followed and the goals of the Water Quality Act of 1972 attained, then present loadings in the river will be reduced; and as a consequence, the probability of possible damage to Quabbin also minimized.

On the other hand, if no additional water is made available to the reservoir, then increased demands may deplete available storage. Declining storage volumes, in turn, will cause an overall loss in water quality. In addition to this possible reservoir water quality deterioration caused by reduced storage levels, supply shortages in the receiver area could also cause a loss in environmental quality for those communities served by the system.

Although exact quantifications of all potential impacts could not be defined, basically because of the present state of the art of ecological investigations, the relative probability of impacts occurring was defined. A summary of these impacts are included in the main report, and a full description of the studies is given in Appendix D - Water Quality Studies of Connecticut and Millers Rivers and Quabbin and Wachusett Reservoirs.

Followup studies of those parameters which require further detail are presently under way with sponsorship from the Metropolitan District Commission.

Finally, if the project was implemented, the additional water supplied would be returned as waste water. If this effluent was not treated adequately, it could cause a degradation of water quality in the receiver area. However, the Water Quality Act of 1972 calls for full treatment of waste discharges by the early 1980's.

D. Other Alternatives

In this report, a wide range of alternatives to the Northfield Mountain Project was investigated. Included in these alternative were other possible diversions, use of new technology as a means of augmenting existing supplies, non-structural approaches such as reduction of demand and the evaluation of the no-action alternative. A description of these alternatives and their potential as solutions to the existing prcblem are summarized in the following paragraphs.

1) No Action

In the evaluation of this alternative, it was assumed that any failure to implement additional supplies for the study area would cause socio-economic impacts on serviced communities. To verify this assumption, a quantification of these impacts was necessary.

Estimates of impacts caused by a no-action policy can be expressed in two different ways. First concrete losses without the diversion total $84 million to 1990 and $528 million to 2020 if average runoff conditions prevailed. Under drought conditions, concrete losses without diversion total $201 million to 1990 and $623 million to 2020. Categories included in these totals encompass industrial, city emergency, city, revenue: commerce, sprinkling, business investment and domestic investment losses.

Social impacts in communities serviced by the supply system under a no-action alternative would be principally "shadow costs" of the concrete losses. As municipal efforts turn to finding other sources of supply, building bans to hold the line on new demands are a likely eventuality. Second-order effects of expenditures on water searching manifest themselves as slowed school building programs, poorer municipal services (such as fire protection) and a general malaise in the region's development plans. In many ways, these effects are reflected in attitudes about the desirability of the community as a place to live and work. The net result could be stagnated growth, hostility toward other communities able to lure industries unable to locate in the water short municipalities.

In addition to socio-economic impacts, a second major impact could occur with the no-action alternative. This second impact regards the probable deterioration in water quality within Quabbin Reservoir which could be caused by lowered reservoir volumes.

Based on the evaluation of the socio-economic and environmental impacts, the no-action alternative has many disadvantages. Use of this alternative, therefore, does not offer a realistic solution to the short range needs of the study area.

2) Weather Modification

The primary source of the water used for public and private water supply in Massachusetts, as in most humid areas, is precipitation falling directly on the areas concerned. It follows then that if precipitation

can be increased in a regulated manner, the water supply can also be increased. To this end, several major agencies such as the National Oceanic and Atmospheric Administration (NOAA), the United States Bureau of Reclamation, the American Meteorological Society, and the National Science Foundation are investigating ways of productively modifying natural precipitation patterns. The primary focus of research is in the area of cloud seeding.

Research has continued to improve the state of the art of weather modification by cloud seeding and other means. At best, however, weather modification is still an inexact science. Studies are unable to predict optimum cloud conditions and seeding results with any degree of accuracy. It is the conclusion of this section, therefore, that at this time weather modification operations to augment water supplies in Massachusetts does not appear to be a viable solution to the immediate water supply problem.

3) Desalinization

Desalinization, the process in which brackish and salt water is converted to fresh, is currently being used in some parts of the world as a viable, economically feasible source of fresh water. This process thus was considered for its potential as a future alternative solution to the water supply needs of eastern Massachusetts.

The conversion of saline to fresh water is accomplished through four major processes: distillation-evaporation, membrane separation, crystallization, and chemical differentiation.

Desalinization by numerous processes is already feasible in parts of the world when the natural water supply is either scarce or of poor quality. In these areas, the relatively high costs of water produced by desalinization are justified. Research completed by the Office of Saline Water has indicated that when larger capacity plants are designed and in production, the costs could ultimately be reduced to approximately 50¢ per thousand gallons in the size range of the Northfield Mountain Project, although a recently proposed California plant would produce water at 73¢ per thousand gallons. Even at this reduced cost, however, desalinization is not competitive with present costs of developing natural surface and sub-surface water supplies. For example, costs of water from this report's recommended project is about 15¢ per thousand gallons.

Aside from the economic costs involved with desalinization, the Office of Saline Water is also investigating the potential hazards to the

environment. In considering placement for any type of desalting plant, environmental factors are as important as any other factor. Pure water is not the only product. A plant will produce extremely concentrated brine as an effluent, plus any waste products from the power source such as soot, heat, smoke, toxic gasses, etc. So far as brine is concerned, this brine from distillation plants is of high temperature, higher chloride content and may contain concentrations of copper which may prove injurious to the environment. Two methods of brine disposal have been studied: (1) evaporation to dryness; and (2) deep-well injection. Evaporation is expensive, though this is highly dependent on land costs presently quite costly in urban areas such as this report's study area. Injection method costs are estimated at 25 to 70 cents per 1,000 gallons of brine. Such costs must be added to plant production and distribution costs to arrive at a true cost of water from this technology. At present, the Office of Saline Water is investigating other methods of brine disposal.

On the basis of the economic costs and environmental problems associated with this technology, this report concludes that desalinization not be considered at this time as a viable alternative source of water in eastern Massachusetts for the short range water supply problems. When and if the technology and efficiency of this process is refined so that it is economically and environmentally competitive with other methods of supplying water, its feasibility can be re-evaluated.

4) Importation

During the crisis years of the sixties' drought, many newspaper and periodical articles pondered the possibility of diverting water from extra-regional sources as a solution. One of the major basins often mentioned as a water supply source for the Northeast was the St. Lawrence. As an alternative to developing local resources to meet future water needs, an investigation was made regarding the feasibility of diverting St. Lawrence flow to meet future needs.

Engineering studies were conducted to assess various methods and quantities of development from the basin. Cost estimates were prepared for projects which would service all of the Northeast through the year 2020. Construction costs for such facilities were estimated to be as high as 8.5 billion dollars excluding any necessary water treatment costs. Water delivered from such an undertaking would cost substantially more than similar volumes made available from local resource potential.

In addition to the high cost of water, this alternative also has several other major disadvantages. First, the nature of the project would not allow stage development. Thus, large expenditures of funds would be required for distant long range needs. Second, since the basin is international, negotiations with Canada would have to be held and a treaty consummated prior to diversion. Assuming that Canada would be favorable to such negotiations, at best, any treaty would be in the distant future.

Based on the results of investigations conducted as part of this report, the importing of water to meet short range water supply needs does not present a viable alternative for the Southeastern New England Region.

5) Waste Water Reuse As A Municipal Supply

Waste water reuse, especially in industrial process application, has been economically successful in many sections of the country.

Other uses to which treated waste water has been applied include irrigation of both crop land and lawns, as a fresh water barrier against salt water intrusion, and in some cases as a source of supply for formation of recreation lakes and ponds.

Direct reuse of waste water effluent as a public water supply, however, has not been utilized to a large degree. Advanced waste treatment research and development programs at the Federal level are continuing, and pilot plant studies such as the noted Lake Tahoe project are apparently meeting with some success in producing a high quality effluent.

The current Drinking Water Standards do not apply to direct reuse of reclaimed water for drinking. Health officials feel many questions remain unanswered which must be fully investigated if renovated waste water is to be considered for drinking water purposes. Research is considered vital before development of intimate personal-contact uses of renovated waste waters.

The future of direct waste water reuse particularly in industrial applications seems promising. Future water demand forecasts for industrial usage used in this report, in fact, anticipate greater recycling of water in the industrial sector.

Use of renovated waste water as a regular domestic supply, however, requires full results of proposed research. Until such research is

completed, waste water reuse as a municipal water supply is not a viable alternative to meet short range supply needs.

6) Ground Water Resources

A study[1] of the ground water resources of Massachusetts was prepared for the Corps of Engineers by the United States Geological Survey. The study was based upon analysis and interpretation of available data and did not include any new exploratory work. The objectives of the study included an estimate of the area extent and sustained yield of principal aquifer reservoirs which might be used for supplementing municipal and industrial water supplies.

The survey of ground water resources indicated that the aquifers in Plymouth County and parts of Cape Cod have the capacity to sustain long term, large magnitude withdrawals. The water demand on Cape Cod is increasing at a fast rate; therefore, this area is not considered in this report. The Plymouth County area studied comprises 300 square miles and its estimated safe yield is 300 mgd. This estimated rate exceeds the required quantity established as a goal of this study. Thus, it was concluded that the Plymouth County area could offer a viable alternative source of water supply for eastern Massachusetts.

Cost estimates for the necessary resource development were then prepared. Major development items included in these estimates were land acquisition, cost of ground water well development, water treatment facilities, pumping installations and connecting aqueduct system to the metropolitan service area. The estimated construction cost for the ground water development per million gallons per day (mgd) capacity is about 1.2 million dollars. Costs for the Northfield Mountain project, on the other hand, are estimated to be about $600,000 per mgd capacity. Annual costs of ground water development which includes interest and amortization; maintenance, repair and operating cost; and major replacement costs are estimated to require charges of about 30¢ per 1000 gallons produced. Annual costs for the Northfield Project would require about 15¢ per 1000 gallons produced.

In addition to the economic costs associated with development of the ground water alternative, there are also potentially significant environmental and socio-economic impacts. For example, land taking activities associated with sanitary protection of the various wells may be substantial. Preliminary estimates of necessary land acquisition for

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[1] This investigation was conducted as part of the feasibility study of potential engineering alternatives in the study area.

the wellfield development indicate 1,000 to 1,500 acres of land would be necessary. This compares quite unfavorably with the 40 acres estimated to be required for the Northfield Mountain water supply project.

Connecting pipelines between wells in the wellfield and transmission facilities to point of use would require a large amount of surface construction. Such extensive surface construction would have an impact on the environment in the vicinity of the wellfield and transmission facilities. Since portions of the aqueduct systems would pass through heavily urbanized areas, disruption would be expected to be extensive.

Since all water developed from the wellfield would have to be pumped to the consumer, this alternative would utilize large amounts of electricity. Thus, depending on the method used to provide this power, impacts on the environment can be expected.

The Northfield Project would utilize off-peak power; therefore, no additional potential environmental damage would accrue because of power requirements.

On the basis, then, of cost comparisons and potential socio-economic impacts, use of ground water does not appear to offer an attractive alternative to the proposed project.

7) Dual Water Supply Systems

An alternative which has been receiving attention of late has been the use of dual water supply systems. In these systems, a hierarchy of water supply would be established whereby higher quality supplies could be used to furnish a potable source for drinking, cooking, dishwashing, cleaning, bathing and laundering. All other uses could be furnished by a second supply of lesser quality.

Two general methods have been suggested for such a dual system. The first is the possibility of recycling at the point of usage. Under this scheme, drinking, washing and bathing water would undergo treatment and then be further utilized as toilet flush water and outdoor uses. It is estimated that such a system could reduce domestic water use by as much as 50%.

Various systems for in-house reuse or for outdoor usage have been proposed, and some are being marketed on a small scale.

Advantages to this system beyond potable water consumption reduction are the reduction in sewage water volume, sewer pipe and pumping requirements. Capital cost outlay for such a system based on limited

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cost data would be over twice as expensive as water delivered from this report's recommended project. Other disadvantages to this alternative lie with its limited application and accompanying operational experience, potential problems of odor and other aesthetic considerations. Health officials in general have not expressed their acceptance or rejection of such systems. However, their general apprehension on introducing less than potable water into the home environment could also reasonably be expected with regard to any system of this nature.

The second method which has been suggested for delivering higher and lower quality water for various uses would require a second distribution system. This second distribution system would carry river water or even sea water to supplement the high quality primary supply source.

To estimate costs for such a system, a report on the New York City area, prepared as part of the NEWS Study, was utilized. Based on the results of that investigation, preliminary capital cost estimates for such a dual system would be about 6.5 million dollars per mgd saved. The Northfield Mountain Project recommended in this report is estimated to cost about $600,000 per mgd. Therefore, use of a dual supply distribution system as an alternative would be an extremely expensive alternative.

In summary, then, use of dual water supply systems to meet immediate short range supply needs does not offer an alternative to the recommended project in this report. Of the two methods, the system which would recycle water at the point of usage holds the more promise for future application.

8) Other Diversion Sites

In addition to the Northfield Mountain Diversion proposal described in this report, a number of other diversion possibilities were also evaluated.[1] These other possible sources included diversions from: the mainstem Connecticut River at other than the Northfield Mountain location; other major tributaries of the Connecticut River, namely, the Deerfield and Millers Rivers; the mainstem of the Merrimack River and the Sudbury River, a tributary of the Merrimack, formerly extensively used by the MDC.

The possibility of diversions from the Millers River, a tributary of the Connecticut River, offers a viable companion source which when combined with the yield of the Northfield would allow serviced

communities to meet short range needs. Development of this Millers River Basin potential is the subject of another Interim Report of Survey.

Other alternative development of the Connecticut River Basin to meet short range needs such as the Deerfield River or another location on the Connecticut River itself could provide an equivalent yield to that of Northfield Mountain. Development of either of these proposals, however, would be more expensive than the Northfield Mountain Project (or the Millers River Basin Project). Aside from economic costs, neither alternative presents any clear cut advantage from an environmental or socio-economic viewpoint.

As an alternative to further diversions from the Connecticut River Basin, the potential of developing the mainstem Merrimack River was also investigated. At present, the physical, chemical and bacteriological quality of the river is poor. For years, the river has been subjected to major discharges of municipal wastes.

An investigation is feasibility detail[1] was conducted to assess methods of improving water quality within the river. At present, an Interim Report of Survey by the NEWS Study is evaluating alternative waste treatment techniques which would improve the river's quality. As a companion study to the waste water element, investigations in survey detail on the river's potential for water supply development are also being conducted.

Based on studies to date, use of the river to meet longer term supply needs holds promise. Use of the river to meet immediate needs within the study area, however, does not appear to offer an attractive alternative to this report's recommended project from either an economic or public health standpoint.

One of the earlier historical supply sources of the MDC was development on a portion of the Sudbury River Basin, a tributary of the Merrimack River. In 1947, in response to the availability of supply from Quabbin Reservoir and the higher quality water from this source, the Massachusetts Legislature transferred control of a number of supply reservoirs to the Department of Conservation.

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[1] The Merrimack: Designs for a Clean River: Alternatives for Managing Wastewater in the Merrimack River Basin, September 1971, prepared for the Northeastern United States Water Supply Study.

With its existing available supplies, the MDC is presently re-evaluating the potential which the full Sudbury system may have. The Sudbury Basin waters, however, have a number of reported water quality problems, thus water treatment facilities would be necessary to develop this source. Based on preliminary cost figures, this redevelopment could cost about twice that of this report's recommended project.

In summary, then, the redevelopment of the Sudbury River Basin could add an attractive increment to the region's available supplies. The redevelopment plan needs further study for a full assessment of its potential; and if implemented, it would be fully compatible with this report's recommended project.

9) Water Demand Control

The NEWS Study, cognizant of the narrow margin separating available yield and consumer demand, conducted studies on methods available to alleviate this critical water supply situation. Two general approaches to the problem were investigated: the first considered various methods of increasing the supply available to the system; the second approach summarized in this section was investigation of methods whereby demand could be curtailed.

There are basically five methods which have been suggested as effective in controlling demands on water supplies. These are:

(1) Changing from flat-rate to metered supply
(2) Increasing the price of metered supply
(3) Imposing of restrictions on water use
(4) Utilization of water-saving devices
(5) Public Water Conservation Education Programs

Each of these methods, outlined above, are described in the following sections as they might apply to the demand forecasts prepared for this report.

(1) Metering

The installation of meters which measure the amount of water used by a consumer have been shown to be effective in varying degrees in reducing demand for water supply. With metering, the customer is now

charged for the quantity of water used, instead of being charged a flat rate for a period of time regardless of quantity used. Most of the studies conducted regarding the effects of metering indicate domestic in-house use is relatively in-elastic, but lawn sprinkling use and some industrial applications apparently are affected.

Use of metering then appears to present a good opportunity for conservation of a resource. In the Boston area, however, application of this technique to reduce demand is quite limited. Most municipalities in eastern Massachusetts already meter extensively. For example, the customers of communities served by the MDC are presently 96 percent metered. Complete metering, therefore, would affect only 4 percent of service connections in this system and not, therefore, affect to any significance, water supply demands forecast in this study.

(2) Pricing Effects on a Metered Supply

A number of articles have appeared in recent years in water supply and water resource professional journals regarding the impact of price increases on water demand. All of these articles attempt to quantify the constraining influence which pricing may have upon demands. In these articles, a number of various pricing techniques have been suggested for administration of price hikes. These include general increases in price levels, seasonal pricing and increasing block rates for varying usage of water. Aside from the administrative technique employed, however, the objective of the articles is to define impact of price increases on demand. Generally, the authors, however, are forced to base conclusions on a generally incomplete and sporadic empirical data base.

On the basis of equations submitted by some of these authors, price adjustments would appear to offer an alternative to development of supplemental water supplies. Theoretically, a price increase of 50¢ per 1,000 gallons could be expected to reduce domestic in-house demands by about 34 mgd and a corresponding decrease in lawn sprinkling demand by about 5 mgd. Industrial water use demands are indicated to react by decreasing almost 14 mgd. The total theoretical decrease on the system then with such a price increase would be about 53 mgd.

On the basis of the theoretical equations then pricing would appear to be a valuable tool for conservation of the water resource. A number of questions, however, arise concerning the direct application of these forecast decreased demands to the water supply situation at hand.

First, the empirical data used in the derivation of the domestic use equations, although the most extensive to date, is far from all inclusive. Data used was derived from 21 areas nationwide, which contained about 5000 dwelling units. None of the test areas were located within southeastern New England, although data available from the Middle Atlantic States was used.

In the analysis of industrial water demand reaction, data utilized was quite limited, and other research in this area is almost non-existent. Development of any hard policy conclusions based on such sketchy information is, therefore, uncertain at best.

Second, the derivation of the empirical equations for domestic use was based on a "static" view of cost versus use. That is, the data employed was not an observation of a group of communities' actual reaction to pricing changes. Rather, the equations were developed by using a number of communities, which for a given point in time, had different water use with their individual rate structures. For example, Community A in 1970 used 100 gpcd at a cost of 20¢ per thousand gallons; Community B in the same year recorded an average use of 50 gpcd at a cost of 40¢ per thousand gallons. Based on the approach used by Howe and Linaweaver, the expected decrease in use from Community A with a price increase to 40¢/1000 gallons would be 50 gpcd. Whether the use of such a "static" scenerio to predict dynamic conditions is valid is unknown.

That the equations may not indeed reflect the dynamic situation which would occur with a price increase is particularly suspect with actual operating experience in the Boston Region. For example, in the Boston Region, the MDC increased wholesale prices for its water from $40 to $80 per million gallons in 1954, and $80 to the current $120 per million gallons in 1962. Neither of these price increases was accompanied by a decrease in per capita demand on the system; in fact, demand increased on the system.

To further evaluate the dynamic impact of pricing in an actual operating experience, a survey was made of a privately owned water company which recently applied a 24¢ per 1000 gallons to its water rates. This rate increase raised the cost of water to the consumer from $1.00 to $1.24 per 1000 gallons. The two communities serviced by the company are principally residential, thus the rate increase based on the empirical equation should be expected to result in a demand decrease, or in any event, a decrease in the rate of increase. The company reports, however, that instead of experiencing a decrease in per capita usage,

it experienced a 5 gpcd increase, an increase in excess of that reported in years prior to the price increase.

Based on the actual operating experience of these utilities within Metropolitan Boston, it appears any arbitrary adoption of the empirical equation as a forecast tool with respect to water demand carries a large degree of uncertainty.

Third, all of the studies upon which the pricing-demand relationship was developed have been basically economic studies. No attempts have been made to evaluate or quantify cost to the consumers from either environmental quality or social considerations. Both the social and environmental costs of reducing water demand may outweigh the gains derived from institution of such a policy. Whether, in fact, the costs would outweigh the benefits is unfortunately unknown.

In summary, use of increased water supply prices as a method to conserve a resource may have merit. Yet to be determined, however, are data to support the theoretical impact such increases would have upon the demand within New England. Also unknown with this approach are the social and environmental costs which would be borne by the consumer. It appears then that much work remains to be done on this approach such that it can be evaluated as a viable alternative to increased supply.

(3) Imposing of Restrictions on Water Use

Historically, water utilities have used water use restrictions as a "safety factor" against depletion of supply during a drought. In general, however, most water utilities attempt to avoid restrictions whenever practical. Public reaction to such restrictions, however, is almost always unfavorable, and many examples of such public disapproval can be found in newspaper clippings during the recent sixties' drought.

Imposition of restrictions on water use could not fail to interrupt the existing and planned life styles of communities serviced by a water supply system. As described in the appendix on socio-economic impacts, restrictions on water use, depending on its degree, would have far reaching social and economic costs. On the basis of costs which would be incurred with a restriction policy, it does not appear to offer a viable alternative.

(4) Utilization of Water Saving Devices In-House

Much of the recent increase in municipal water supply by individual consumers has been attributed to the adoption of multiple toilet facilities; water using devices such as automatic clothes and dish washers; and shower installations. Variation in water use between brand names differs markedly. For example, automatic home washers for an 8 pound load require from 32 to 59 gallons per load, while toilets vary from 3.2 to 8 gallons per usage. Information on the impact of domestic water saving appliances on in-house use is limited and variable in quality.

An article[1] presented last year in the American Water Works Association demonstrated possible water savings which could be brought about by adoption of presently available appliances for toilet, clothes washing and shower use. Based on their findings, the authors conclude that there doesn't appear to be current financial incentives for adoption of water saving appliances. They do note, however, that conversely economic costs to consumers from utilizing water saving appliances do not seem great. Presumably, their conclusion refers to replacement costs when currently used appliances wear out. The authors suggest that complete replacement of appliances with water saving models might reduce domestic water use by 32 percent.

A second study[2] of water conservation measures for the Office of Water Resources, U. S. Department of the Interior, also contains some information on water saving devices. In this study, it was noted that increasing use of water by automatic dish and clothes washers over the years has been occasioned by a rise in required performance standards. Thus, customer desires are reflected in the increased water use.

A third study[3] recently completed for the Washington Suburban Sanitary Commission provides a brief review on the effectiveness of water saving measures and the relationship of their use to rate-making policy

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[1] Howe, Charles W. and Vaugham, William J. "In House Water Savings," Journal of the American Water Works Association, Vol. 64, No. 2, (February 1972).

[2] Hittman Associates, Inc., "Main C. Computerized Methodology for Evaluation of Municipal Water Conservation Research Programs," No. HIT-409, Columbia, Maryland, August 1969.

[3] Boland, John J., Hanke, Steve H., and Church, Richard L. An Assessment of Rate-Making Policy Alternatives for the Washington Suburban Sanitary Commission, Prepared for the Washington Suburban Sanitary Commission, September 1972.

formulation. In this report, the authors state "A major deficiency in the data reported by all investigators to date is that it refers to isolated uses of specific appliances and fixtures, but does not reflect actual use conditions."

In reference to the suggestion that 32 percent of the domestic water use could be saved by adoption of water saving devices, the authors state "Such a result implies, of course, no reduction in the actual or perceived efficiency of operation of any of the appliances or futures. In the latter instance, the net reduction in water use is more difficult to predict; however, it should be somewhat less than 32 percent."

Statements made at a number of progress meetings suggested that use of incentives such as subsidies or tax concessions and revision of plumbing codes to require water saving devices would result in substantial water savings. In general, however, the same questions which burden analysis of price as a demand moderation measure also apply to use of water saving devices. Regardless of managerial technique used to implement use of such devices (i.e., subsidy, tax concessions, etc.) the question still remains as to the effectiveness and impacts on water use which may occur. Research conducted to date has been limited. In addition, socio-economic impacts which might occur with a general requirement that older appliances be replaced with the water saving models has not been addressed at all. Environmental impacts generated as a spinoff of producing the new replacement models may also be significant and must be included in any analysis.

In summary, adoption of water saving devices as a method of conserving water supply may have merit in the long run. At present, however, supporting data to measure the impacts of either requiring new housing units or replacement by older housing with water saving appliances is not available. Without this data, evaluation of potential savings as an alternative course of action to the recommended project cannot be documented.

(5) Public Water Conservation Education Programs

Historically, the water supply industry has not advocated wide-scale public water conservation, except in communities where supply or distribution systems were inadequate to meet demand. Recently, however, increased awareness of the need to protect and enhance the environment has required a review of this earlier policy.

At present, two major metropolitan supply systems[1] have adopted a water conservation policy during a time of water surplus. In the past year, both utilities have promoted expanded voluntary customer water conservation through a public education program.

Bill inserts and information handbooks on water-saving measures have been distributed widely. In addition, speeches to individuals, schools and clubs have been employed to inform the public of why the water resource should be used properly and what they can do to help conserve water. Results of the education programs are now being evaluated for their effectiveness.

The Washington utility which has the longest experience record reports results have been encouraging to date; however, major reductions in per capita usage have not been observed.

In addition to voluntary conservation measures, the two utilities are also considering the use of regulatory powers to conserve water. Regulatory measures under consideration include, for example, price increases, utilization of water-saving household appliances and restriction of lawn sizes. All such measures, however, are being carefully evaluated by the utilities because of the many questions, described in earlier sections, which surround use of such devices.

In summary, adoption of public water conservation programs as a management tool has received attention of late. Results on water use modification of the voluntary conservation programs now under way are limited. However, based on the Washington area experience, no major decrease in per capita usage has been observed.

10) Re-Examination of the Swift and Ware Rivers Downstream Release Schedules

At the time diversions were contemplated from the Connecticut River Basin, via the Swift and Ware Rivers, Massachusetts applied to the Secretary of War for authority to make the proposed diversions. After hearing arguments pro and con from Massachusetts and Connecticut, the Secretary permitted diversion of the flood waters of the Ware in excess of 85 million gallons per day between 15 October and 15 June and prohibited the taking of any water except during that period.

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[1] Washington Suburban Sanitary Commission and East Bay Municipal Utility District. Note: both utilities service populations of about 1.1 million each.

With regard to the Swift River, the Secretary permitted diversion of all waters of the Swift except enough to maintain a flow therein of 20 million gallons per day (mgd) or 31 cubic feet per second (cfs). The Secretary did require that during the period from 1 June to 30 November, there shall be released from the impounding dam 71 mgd (110 cfs) whenever the flow of the Connecticut River at Sunderland, Massachusetts is 4650 cfs and 45 mgd (70 cfs); when the flow is more than 4,650 and less than 4,900 cfs.

These findings of the Secretary of War regarding operational schedules for the diversions were later made a part of the Supreme Court Decision, dated March 1931, in the suit between Connecticut and Massachusetts. Since the date of that decision, diversions from the Swift and Ware Rivers have been accomplished under the Secretary of War findings.

During the progress of the NEWS Study, an interested citizens' group suggested the setting aside of the Swift River diversion limitations with the objective of retaining presently scheduled releases within Quabbin Reservoir. The citizen group further suggested any diminution of flow in the Connecticut River could be made up by releases from existing Corps of Engineers' flood control reservoirs. In keeping with this suggestion, an examination was made of the potential which such rescheduling might have on the short-range supply problems.

The drainage area of the Swift River controlled by the Quabbin Reservoir totals 186 square miles. The long-term average annual runoff from the watershed is 187 mgd (289 cfs) of which 32 mgd (50 cfs) has been released downstream in compliance with the existing downstream release schedule.

Thus, the maximum addition to the existing water supply system which could be achieved through re-scheduling would be 32 mgd (50 cfs). To provide this increment, however, all downstream releases with the subsequent "drying up" of the river reach downstream are, of course, impracticable. The question then raised is what level is practicable. A recent study[1] completed for the entire Connecticut River Basin recommends an instantaneous discharge rate, from power reservoirs on the Connecticut River of 0.20 cubic feet per second per square mile of upstream watershed. An application of this criteria to Quabbin

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[1] Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin, Connecticut River Basin Coordinating Committee, June 1970.

Reservoir, for example, would result in a downstream release requirement of 24 mgd (37 cfs). Adoption, then, of such a modified operational schedule could result in an additional 8 mgd being made available. This increment of yield, however, would not begin to meet the short-range needs of this report's study area which are estimated to total an additional 141 mgd. In short, then, a re-examination of downstream release schedules with the objective of conserving such releases for water supply has merit. However, based on the requirement of maintaining a viable river environment downstream from Quabbin, the opportunity for reducing downstream releases does not offer an alternative to the project reported upon in this study.

The spring runoff which occurred in 1972 was of longer duration and of greater magnitude than is usually experienced. As a result, diversions from the Ware River, in compliance with the operation schedule, described earlier, were forced to cease even though flows in excess of 85 mgd were still occurring. This event triggered a suggestion to the NEWS Study that if the 15 June to 15 October no diversion constraint were lifted, large additional supplies of water could be made available to Quabbin.

A computer test was made to determine the impact of the 15 June to 15 October constraint. The results of the computer simulation indicated that only an additional 2.6 mgd might be made available if the 4 month no diversion period currently in effect was terminated.

In the Ware River, as in the case of the Swift River, a re-examination of downstream release schedules may have merit. However, terminating the 15 June to 15 October diversion period constraint does not offer an alternative to this report's recommended project.

E. Coordination

Since the initiation of this work, a determined effort has been made to inform the public of the work's progress. Nine progress meetings were held in the Boston Metropolitan area, generally at Waltham, Massachusetts; the first held on 7 May 1970, with the latest held on 7 June 1972. Attendance at these meetings generally averaged about 50 people, with attendees representing Federal and State Agencies, conservation commissions, the Audubon Society, sportsmen groups, and interested citizens.

In addition to the progress meetings, four informal information meetings have been held within the Millers River Basin. These meetings were held in Athol, Massachusetts on 21 October 1971 and 4 January 1972; in Winchendon, Massachusetts on 2 March 1972; and in Athol, Massachusetts on 8 May 1972.

During December 1971 and January 1972, a series of four formulation stage public meetings were held in Needham, Woburn, Orange and Longmeadow, Massachusetts. These meetings were designed to broaden public participation in the open planning process by describing the on-going studies and receiving audience input.

In July 1972, two late stage public meetings were held at Waltham and Orange, Massachusetts, and the various plans for augmenting water supply systems were discussed and described.

A full description of the coordination held during the study is included in the main report and Appendix H.

4. Conclusions

As recognized in the NEWS Legislation, natural departures from normal precipitation and runoff conditions can have regional impacts on the social well-being of a large segment of the nation's population. The sixties' drought which began in 1961 ultimately through its duration directly affected the water use patterns of more than 20 million people. In 1965 alone, drought-related water shortages and associated problems were severe enough to warrant emergency actions by local, State and Federal agencies. Within Massachusetts, for example, more than 50 cities and towns imposed restrictions on water use.

During and following the drought, a number of communities and regional planning agencies conducted engineering studies to determine methods for augmenting existing supplies. In many cases, new supplies have been developed by communities which would allow them to meet future needs. Investigations conducted by the NEWS Study in Southeastern New England indicate that even with the actions undertaken by local authorities, additional supplies must be made available if future needs are to be met.

In 1969, a feasibility report on possible engineering alternatives to meet the region's needs was prepared by the NEWS Study. A total of 28 projects were identified as possible candidates for implementation to provide an adequate water supply system within the region. The Northfield Mountain project examined in this report was one of the engineering alternatives included in the feasibility study. Upon implementation, output from the project would provide additional supply, as shown on Plate No. S-4, to meet a large segment of the region's future needs.

This report has investigated and assessed all aspects of the water supply situation within the study area. The Metropolitan District Commission (MDC), Boston, is the largest regional system in New England, supplying about two million people in 1970. The MDC relies upon surface water as its supply source, and the present estimated safe yield of these sources is 300 million gallons per day (mgd). In 1971, the average daily delivery of water from this system was about

322 mgd. Available safe yield of the largest regional system in New England has been outstripped by rising supply demands.

The land area encompassed by this study falls within the boundaries of the so-called "megalopolis" which extends from Boston, Massachusetts to Washington, D. C. Latest population estimates for the Massachusetts study area forecast increases from 6.5 million in 1970 to 7.8 million by 1990, and 9.7 million by the year 2020.

Estimates of future water requirements within the region and on the existing regional system demonstrate the need for additional supply. Development of a single regional system to meet 1990 needs of all communities within the study area was not found to be an attractive approach, either from an economic or resource utilization viewpoint.

Based on a review of the area's 1990 water supply needs, it is concluded that the MDC system, as it exists at present, will require additional supply. In addition, studies reveal about 23 communities which may require admission to the system to satisfy their short range (1990) needs.

The estimated total demand for 1990 for presently serviced and other needy communities on the existing regional (MDC) supply sources is calculated to be about 441 mgd. Future demand forecasts were derived using both population and industrial output projections. In general, although some modification of consumer and industrial water usage patterns are included in these estimates, no major modifications or shifts in usage patterns are included.

In order to meet the 141 mgd additional demand, a large number of alternatives were investigated to determine their environmental and socio-economic impacts. Alternatives to the Northfield Mountain project included no action, desalination, groundwater development, waste water reuse, other diversion sites, re-regulation of existing supply sources, local resource development and controlling the water supply demand. Based on the investigations conducted, it is concluded that the Northfield Mountain supply project offers an attractive opportunity for providing early relief to the short range needs.

In the evaluation of the Northfield Project, particular attention was given to the impacts on downstream water users which implementation might cause. All of the investigations indicated minimal downstream effects could be expected with operation of the project.

On the other hand, implementation of the project would provide protection against water shortages and associated socio-economic losses. Estimates of economic losses prevented when compared to project costs demonstrate the economic efficiency of the project. With respect to the Regional Development objective, the project would provide a benefit/cost ratio of 1.2 under average runoff conditions; and under a hypothetical drought situation, the ratio was estimated to be 1.9 In the National Economic Development account, the benefit/cost is estimated to be 1.1 under normal and 1.7 under drought runoff conditions.

In assessing the Environmental Quality Impact, the Connecticut River Estuary, the river itself and the receiving water body at Quabbin Reservoir were examined to determine what changes would accompany the project's implementation. In general, minimal changes can be expected in the river and estuary downstream of the diversion intake. These minimal impacts forecast are due to the relatively small diversion volumes compared with river flow. Within Quabbin Reservoir, the diverted flow may have impacts depending to a large degree on the pollution abatement steps taken. For example, the present waste loads may provide opportunities for localized algae growth or oxygen depletion. The Metropolitan District Commission is currently investigating certain chemical and physical parameters to better define the probable impacts on the reservoir.

Based on all investigations conducted, it is concluded that resources are available within the region which can be developed from both economical and environmental viewpoints. Development of these resources through the Northfield Mountain Project and a companion project (subject of another report) offers a means of meeting supply needs through 1990. The availability of the resource and the opportunity for their development provides an optimistic outlook for the region at least in the short run.

In addition to the conclusion that the Northfield Mountain Project should be implemented, it is also felt that concurrent investigations on water demand and its makeup should be conducted.

For example, detailed breakdown of water use or demand by consumers is not readily available. Although use, on a per capita basis, is readily available, data on how and by whom the water is used is not well documented. Increased per capita demands are, of course, a reflection of the nation's rising standard of living, but the breakdown of this demand into various use categories is poorly understood. A clearer understanding of the breakdown would permit the most efficient long range use of water supply resources.

Household items, which are undoubtedly contributing to increased water usage, include clothes and dish washing machines; multiple toilet facilities, and installation of shower facilities. Among these appliances, a wide range of water requirements per usage is needed. A search of available literature indicates these wide variances in water requirements may not be occasioned by economic or environmental efficiency objectives, but rather the result of independent design criteria. It appears then a rationalization of criteria used in design of water using appliances may offer opportunities for reduction of longer range water needs upon the public supply systems. The true measure of this opportunity would require extensive investigation, including the various appliances' efficient water needs; the impact which re-design would have on consumers; identification of incentives necessary to achieve full use of such devices, such as use of plumbing regulations, subsidies, and the effect which such potential in-house savings may have on future, particularly long range, water demands.

A second area worthy of investigation regards the impact which restructuring of pricing policy as a conservation measure for long range needs may have. Studies conducted to date indicate increases in cost of water supplied to the consumer may decrease use of water by the individual. Data developed to date on this pricing/use reaction has been limited. Thus, any theoretical anticipated decrease in water use caused by a price hike must be viewed as speculative.

In addition, none of the work has addressed the question of whether such price increases would in fact be beneficial or detrimental to the socio-economic objectives of the public water supply consumer. For example, if water rates were raised substantially in excess of the economic costs of delivering the water, the rate increase would, in effect, be a tax placed upon the consumer; consequently, questions of equity then arise. In short, the use of pricing as a conservation tool is an unproven venture, given the present "state of the art" concerning its potential benefits and possible shortcomings. Studies should be conducted, therefore, which address these questions and provide answers as to the impacts of such measures.

During the course of the study, at a number of informal progress and formal public meetings, it became evident that public interest in water supply planning was far from consistent. Meetings held within the Connecticut River Basin or the supplier area always were will attended with high audience participation. On the other hand, at three public meetings held in the Eastern Massachusetts region, the area which could be supplied water from this report's recommended project, less than 50 people attended each of the meetings. It appears that the public

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in Eastern Massachusetts takes its present good quality and available water as unlimited. This attitude can be attributed, in part at least, to the continuing availability of supply made available by the efforts of the local and regional water supply agencies. The question arises, however, whether such casual public concern over their water resources is a healthy state of mind. Many conservation groups at the NEWS meetings characterized this lack of public concern as leading to misuse of the resources through waste. There is no evidence to substantiate this charge in the study region. However, an education program to inform the public about their supply system, its limits and future, is in consonance with good management practice. The development of such an educational program, therefore, not only within the study area of this report, but nation-wide, should be considered as part of any water supply plan.

Throughout the conduct of this study, a number of groups, primarily conservation oriented, have advocated the re-cycling of waste water for water supply uses. In some cases, such as in certain industrial processes, effluent from waste treatment facilities can be utilized. The use of such waste water effluent, regardless of the degree of waste water treatment, as a source of supply for municipal systems is not sanctioned at this time. Echoing the position of the Division of Water Supply, Environmental Protection Agency, State and local health officials and professional water supply engineers, any application of reused water as a municipal supply would require a considerable amount of research on associated potential health hazards. Since, in many regions, less than desirable sources may be needed in the future, it is imperative such research be accelerated.

The Northfield Mountain Water Supply Project would be an important supply increment in the regional plan for the metropolitan Boston area and is compatible with the short and long range water resource development objectives of the region. Included in the regional plan for the Boston area would be one of the Millers River Basin alternatives described in a companion report. Also, there is the possibility of utilizing the South Sudbury River and/or the Merrimack River for future demands. Studies should be conducted to determine whether certain measures designed to conserve and moderate water demand should be implemented to reduce the size of needed long range water supply developments. For the region as a whole, water resources are available which can be developed efficiently from both an environmental and economic viewpoint to meet the water demands. Sources include the Merrimack, Taunton, North and Connecticut River Basins, together with local groundwater sources. The future water supply view of the area, therefore, can be described as optimistic. However, a continuing planning program, dynamic in nature, must be pursued to insure adequate, safe, dependable water supplies are available when necessary.

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

SECTION I

GENERAL

1. Purpose

The severe five-year sixties' drought which plagued the Northeastern United States revealed a soon to be critical water shortage within eastern Massachusetts. More important detailed examination accomplished in this study indicates that many water supplies available to this area are inadequate to meet today's needs and the area's expanding population and industrial growth. This report presents a plan for diverting excess high flows from the Connecticut River Basin, to meet a portion of the future water supply needs within eastern Massachusetts. The study area is shown on Plate No. 1.

2. Authority

The Northeastern United States Water Supply Study (NEWS) was authorized by Congress under Title I of Public Law 89-298, enacted on 27 October 1965. Congress thereby recognized that assuring adequate water supplied for our great metropolitan centers had become a problem requiring the assistance of the Federal Government in its resolution.

Under direction of the Congress, the Secretary of the Army, acting through the Chief of Engineers, was authorized to cooperate with Federal, State and local agencies in preparing plans in accordance with the Water Resources Planning Act, Public Law 89-80, to meet the long-range water needs of the Northeastern United States. In meeting these needs, this plan may provide for the construction, operation and maintenance by the United States of a system of major reservoirs, major conveyance facilities and major purification facilities within the study area. The Chief of Engineers in turn assigned responsibility for the NEWS Study to the Division Engineer, North Atlantic. This report is submitted in partial fulfillment of the above authorization and will be incorporated as part of the overall NEWS effort. A plan of the entire NEWS study area is shown on Plate No. 2.

3. Scope of Studies

Studies conducted as part of this report included the following tasks:

a) Detailed projections of population, water demand, and potential service areas, principally within Eastern Massachusetts as well as within the Connecticut River Basin, were completed in this study.

b) Geologic investigations with existing sub-surface data of proposed tunnel and conduit routes and reservoir sites were accomplished.

c) Requirements for waste and water treatment studies were investigated.

d) Ecological and environmental studies were completed which consider the effects, both immediate and future, of the various proposals on the environment and ecology of both the Connecticut River, its estuary, and the receiving storage impoundment at Quabbin Reservoir.

e) Hydrologic and hydraulic analyses.

f) Economic studies and evaluations.

g) Estimates of quantities and costs of major items of construction.

h) Alternatives to the proposed project, ranging from the development of small local water supply sources to an assessment of desalination, waste water reuse and weather modifications.

i) Inclusion of multi-purpose applications within the proposed water supply project.

j) An investigation of the broad socio-economic impact of the proposed project.

Since the initiation of these studies, a determined effort has been made to inform the public of the work's progress. Beginning in May 1970, a total of six formal public meetings, nine progress and four informal informational meetings were held. At all of these meetings, progress on various elements of the NEWS Study was described.

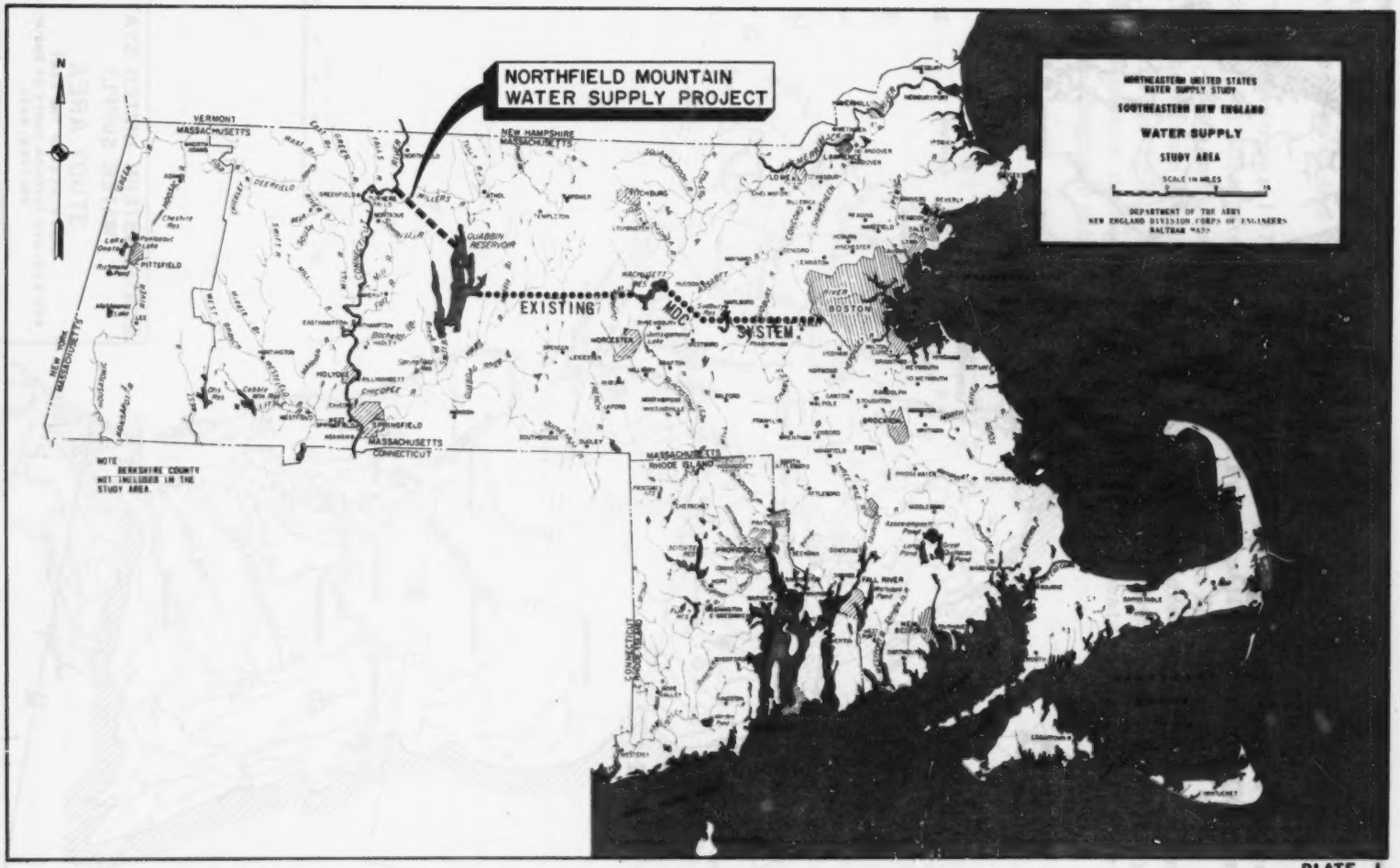
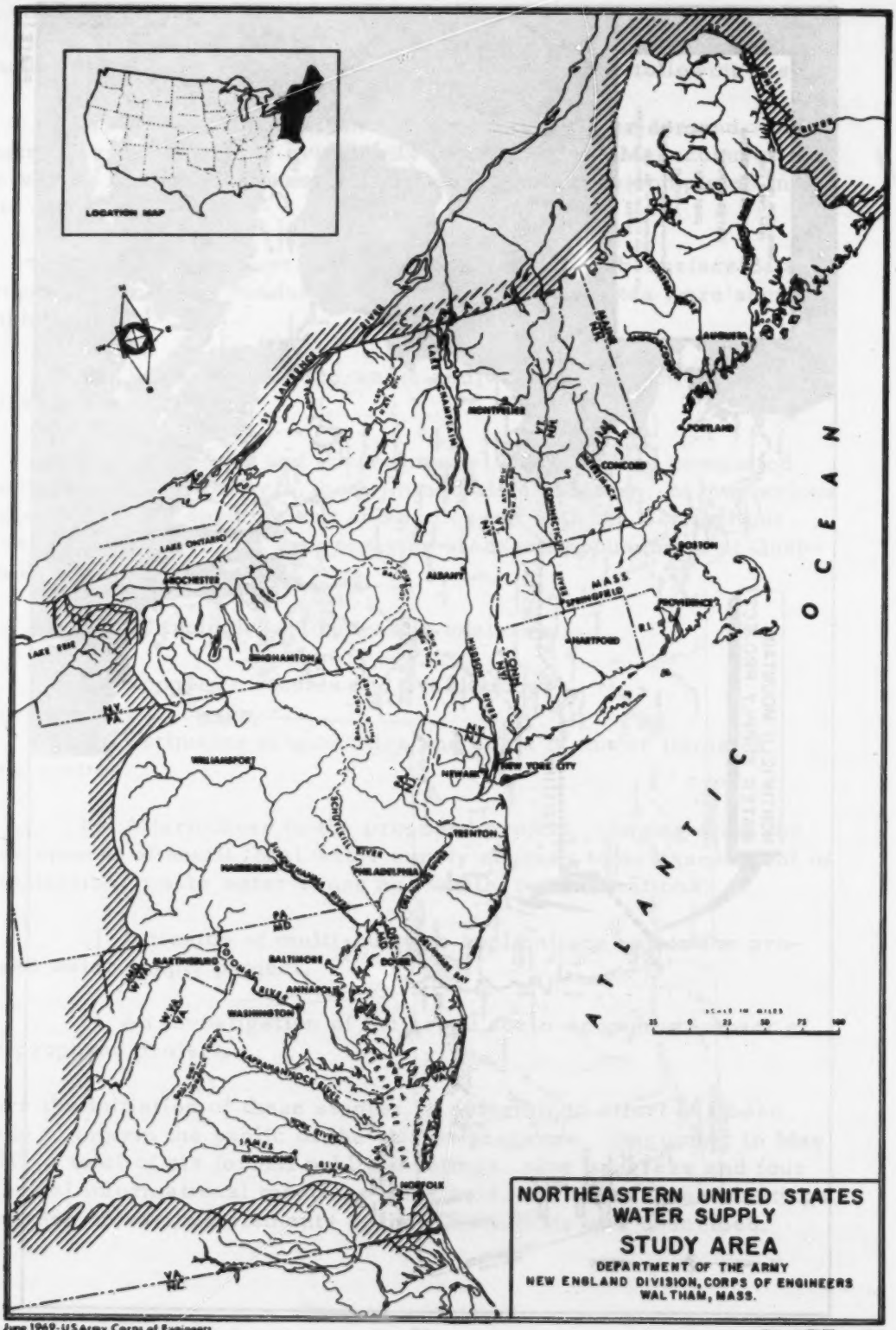

NORTHFIELD MOUNTAIN
WATER SUPPLY PROJECT
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
SOUTHEASTERN NEW ENGLAND
WATER SUPPLY
STUDY AREA
SCALE IN MILES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION CORPS OF ENGINEERS
BALTIMORE, MASS.
N
VERMONT
MASSACHUSETTS
NEW HAMPSHIRE
MASSACHUSETTS
QUABBIN RESERVOIR
EXISTING
MDC
SYSTEM
PITTSFIELD
SPRINGFIELD
MASSACHUSETTS
CONNECTICUT
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
NOTE
BERKSHIRE COUNTY
NOT INCLUDED IN THE
STUDY AREA.

PLATE 1



June 1969-US Army, Corps of Engineers

PLATE 2

Questions, answers and opinions were interchanged between the study team and audience. Input gained at these meetings served to guide the direction of the tasks and the final recommendations.

At the November 1971 progress meeting, a number of citizens stated a desire for formation of a "Citizens Participation Board." The purpose of this group was to act as an ombudsman for citizens in the watershed from which diversion of water was contemplated. Initiated in December 1971, this board has worked with members of the study team to insure that views and concerns of the watershed citizens were known throughout the conduct of this study.

SECTION II

PRIOR REPORTS

4. Published Reports

A. General

A large number of reports have been prepared on the various rivers within the Connecticut River Basin. These reports, prepared by Federal, State and Regional Agencies, cover many areas of resource interest, both in the public and private sectors. In the Corps of Engineers on-going flood control program, for example, there have been completed, beginning in calendar year 1926 and continuing through 1968, a total of 25 reports in response to separate Congressional directives. In the area of navigation, from 1911 through 1969, the Corps had submitted 18 separate reports, while six summary reports on flood plan information have been submitted as guides to local municipalities. In addition, two multi-purpose flood control reservoirs recently constructed have included water supply storage under the provisions of the Water Supply Act of 1958. Few of these prior Federal reports, however, address themselves to water supply planning, thus a complete listing was not considered necessary for this report. A few of the more pertinent Federal reports are included in the following section.

State and Regional Planning Agencies, however, have been active in preparing plans for future water supply needs. Wherever applicable, these reports have been reviewed and considered in the preparation of this study. A listing, including these agencies and some of their reports, is given in paragraphs 4C. and 4D.

B. Federal

The land and water resources and flood control needs have been considered in the following published reports:

1) "308" Report, dated 11 February 1936, was submitted to Congress with recommendations which included the construction of ten flood control reservoirs on the tributaries of the Connecticut River in the states of Vermont and New Hampshire.

2) "House Document 455, Seventy-fifth Congress, 2nd Session" was published in 1937. This report proposed a revised comprehensive plan for flood control of the Connecticut River and its

tributaries consisting of 20 reservoirs and dikes at seven locations. The report recommended that the authorization for additional reservoirs be deferred and that the authorized project be modified to provide for the protection by dikes and related works of cities.

3) "The Resources of New England - New York Region," as authorized in Section 205 of the Flood Control Act of 1950 (P. L. 516-81st Congress, Second Session) together with a Presidential Directive of 9 October 1950, establishing a six-member Federal interagency committee. This report recommended that the river basin and regional plans set forth in the report serve as a guide for the development, conservation, and utilization of land, water, and related resources of the New England - New York Region. The report is commonly referred to as NENYIAC. Part I and Chapter I of Part 2 are printed as SD 14, 85th Congress, 1st Session.

4) "Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin," was published in June 1970. This report was authorized in resolution of the Committee on Public Works of the United States Senate, adopted 11 May 1962. The purpose of the report is to present a comprehensive plan of development that will serve as a flexible guide for the optimum utilization of the water and related land resources of the basin. Specific objectives of the studies made for this report were: to isolate the basin's problems and potentials related to its water and land resources; to develop possible solutions to these problems and formulate from them projects and programs to satisfy the immediate (1980) and to identify potential measures for long-range (2020) needs.

The study was directed and reviewed by the Connecticut River Basin Coordinating Committee composed of representatives of the Departments of Agriculture; Army; Commerce; Health, Education and Welfare; and the Interior; the Federal Power Commission; and the States of New Hampshire; Vermont; Massachusetts; Connecticut; and the New England River Basins Commission.

In formulating a plan to meet the needs and desires of the people in the Connecticut River Basin, the Coordinating Committee strove to insure that all elements be compatible and that programs and projects be flexible and adaptable to unforeseen demands and changing patterns of needs. Alternatives were given due and responsible consideration.

The Committee developed a plan to accomodate two time frames; namely, an "early action" plan covering the next ten years; and a long-range framework type plan embracing requirements and

opportunities to the year 2020. The 1980 Basin Plan, as recommended by the Coordinating Committee, is estimated to cost $1,800,000,000 (based on 1969 price levels). The proposals are presented in ten broad element categories as follows: Water Quality, Power, Outdoor Recreation, Preservation of Sites, Anadromous Fisheries Restoration, Resident Fish and Wildlife, Water Supply, Navigation, Upstream Water and Related Land Resource Potential, and Flood Control and Large Multiple-Purpose Reservoirs.

The water supply element of the 1980 Basin Plan is presented in five parts, four of which concern water supply requirements for the four basin States and part number five in regard to out of basin diversion of water supply.

Water supply needs are presented for each of the basin States in detail. The study finds that the natural abundance of available surface and groundwater supplies, if properly developed, can meet all projected municipal and industrial needs of the basin. Out of basin needs for the 1980 time period are recognized as being met by flood-skimming operations such as that proposed in conjunction with the Northfield Mountain pump storage power project. Similar flood-skimming operations potential was identified at the existing Corps of Engineers' Tully Reservoir located in the Millers River watershed.

Thus the need for, and potential of, servicing out of basin water supply demands from the Connecticut Basin was identified in the comprehensive study. The Northfield Mountain Water Supply Project, described in this report, therefore, is compatible (1) with the comprehensive Basin Plan.

5) "North Atlantic Regional Water Resources Study" was published in June 1972. This report was authorized in Section 208, Public Law 89-298, 27 October 1965. The purpose of the report was to present a comprehensive framework plan for the management of water, related land and other environmental resources in the North Atlantic Region of the nation, a region which closely approximates the NEWS study area.

The study was directed and reviewed by the North Atlantic Region Water Resources Study Coordinating Committee. This Coordinating Committee was comprised of representatives of the Departments of Agriculture; Army; Commerce; Housing and Urban Development; Interior; Transportation; Environmental Protection Agency; and the Federal Power Commission. The States of Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania,

(1) See New England River Basins Commission letter of 15 June 1973 in Appendix N.

Delaware, Maryland, West Virginia, and Virginia also served on the Committee as well as representatives of the District of Columbia, Delaware River Basin Commission and the New England River Basins Commission.

The Coordinating Committee used a multiple objective planning process to consider alternative objectives, needs, devices, benefits and costs to develop a 50-year management program for the Region's water and related land resources. Answers to all questions are not provided in this report. As a framework document only, guideposts are presented that will lead its users to more direct routes in finding answers related to water resources management and will lead users away from or warn them of potential pitfalls.

6) "Organizational, Legal and Public Finance Aspects of Water Supply for Southeastern New England the Metropolitan Area of New York City - Northern New Jersey - Western Connecticut," July 1972. This report was prepared as part of the overall Northeastern United States Water Supply Study (NEWS). The purpose of this report was to analyze organizational, legal, and economic problems of water supply within the study area. Alternative solutions to the problems are described and discussed.

The results of engineering studies supplemented by the results of this institutional feasibility study constitute the tools with which the Corps of Engineers and other agencies and organizations concerned may reach a decision on which of the various alternatives more detailed study effort should be concentrated.

7) In addition to the published reports described in the previous paragraphs, a report entitled "Feasibility Report on Alternative Regional Water Supply Plans for Southeastern New England" was recently prepared by the New England Division Division for the North Atlantic Division as part of the Northeastern United States Water Supply Study (NEWS). This report, as described in the summary, assesses the capability of the public water supply systems within eastern Massachusetts and Rhode Island to meet future needs. Plans and alternatives are proposed which when added to the present systems, would assure future adequate water supply for the study area.

C. State

1) Massachusetts

Massachusetts State Agencies with responsibility in water supply planning, construction and certification are the Department of Natural

Resources, the Metropolitan District Commission, and the Department of Public Health.

Studies regarding the present water supply situation in the Boston Metropolitan Region have provided a significant input to the preparation of this report. Some of the regional reports include:

a) Massachusetts Senate Document No. 1216, Report of the Metropolitan District Commission to Make an Investigation and Study Relative to Increasing the Sources of Water to the Metropolitan Water District and Increasing Membership of Said District, December 1971.

b) Hill and Lind, Inc., Report on Ipswich River District Water Supply, Prepared for the Massachusetts Water Resources Commission, Division of Water Resources, September 1971.

c) Massachusetts Senate Document No. 1008, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water From Millers River and Other Sources Into Quabbin Reservoir, March 1971.

d) Massachusetts House Document No. 5543, Report of the Special Commission Relative to Providing Funds for Extension and Development of Water Supply Sources and Diversion of Water from Connecticut River to Quabbin Reservoir, May 1970.

e) Massachusetts Senate Document No. 1230, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water From Millers and Other Sources Into Quabbin Reservoir As Required by Chapter 46, 1967, March 1969.

f) Massachusetts Senate Document No. 1095, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water from Millers River and Other Sources into Quabbin Reservoir, December 1966.

g) Massachusetts Senate Document No. 808, Special Report of the Metropolitan District Commission Relative to Diversion of Excess Water from Millers River into Quabbin Reservoir, January 1966.

h) Massachusetts House Document No. 4100, The Public Water Supply Resources of the Ipswich River, Prepared for the Massachusetts Water Resources Commission, Division of Water Resources, January 1965.

2) Connecticut

In the State of Connecticut, responsibility for the adequacy and safety of public drinking water supplies lies with the Connecticut Department of Public Health. In addition to this agency's work, a large amount of regional water supply planning has been conducted by regional planning agencies and the private investor-owned water supply companies. In 1967, an Interagency Water Resources Planning Board was formed to coordinate and report the State's water resources. The agencies which make up the Board are the Office of Statewide Planning, Department of Environmental Protection and the Department of Public Health. Reports prepared by Connecticut State Agencies and reviewed as part of this study include:

a) Statewide Long Range Plan for the Management of the Water Resources of Connecticut, Phase I, Prepared by the Interagency Water Resources Planning Board, 1971.

b) Dewey and Kropper, Engineers, Inc., Effect of Proposed Northfield Mountain Diversion Project on State of Connecticut's Interests, Prepared for Connecticut Water Resources Commission, May 1966.

D. Regional Planning Agencies

Seven regional planning agencies in Massachusetts and Connecticut are located in the vicinity of and downstream from this study's project area. Those within Massachusetts are the Franklin County, Department of Planning and the Lower Pioneer Valley Regional Planning Commission. Within Connecticut, five agencies have been active. They are the Capitol Region, Midstate, Central Connecticut, Connecticut River Estuary and Southeastern Connecticut Regional Planning Agencies. A number of reports regarding future water supplies of the agencies' respective regions have been prepared and include:

1) Unpublished Report on Water Supply Needs in Franklin County, Massachusetts, 1971.

2) Metcalf and Eddy, Engineers, Inc., Water Supply Facilities, Prepared for the Lower Pioneer Valley Regional Planning Commission, March 1970.

3) James S. Minges and Associates, Alternative Plans for Regional Utilities Study, Prepared for the Capitol Region Planning Agency, June 1968.

4) Maguire, Charles A. and Associates, Regional Water Supply and Distribution in the Central Connecticut Planning Region, Prepared for the Central Connecticut Regional Planning Agency, March 1969.

5) Water Supply Plan for the Southeastern Connecticut Region, Volume 2, Recommended Plan, Prepared by the Southeastern Connecticut Water Authority and the Southeastern Connecticut Regional Planning Agency, February 1970.

In addition to reports prepared by planning groups in the Connecticut River Basin, water supply studies prepared by regional groups in eastern and central Massachusetts were also reviewed. These included:

6) Camp, Dresser and McKee Engineers, Inc., Alternative Regional Water Supply Systems For the Boston Metropolitan Area, Prepared for Metropolitan Area Planning Council, February 1971.

7) Metcalf and Eddy Engineers, Inc., Water Supply and Sewage Planning in Central Merrimack Valley Region, Prepared for Central Merrimack Valley Regional Planning Commission, September 1970.

8) Northern Middlesex Area Commission, Regional Utilities, Volume 2, Alternative Plans for Sewer and Water Facilities, July 1969.

9) Metcalf and Eddy Engineers, Inc., Report to Old Colony Planning Council, Brockton, Massachusetts, on Phase Three of Water and Sewerage Study, March 1971.

10) Tippetts - Abbett - McCarthy - Stratton, Regional Study for Water Supply, Sewerage Disposal and Drainage, Southeastern Massachusetts, Phase II, Prepared for Southeastern Massachusetts Regional Planning Commission, April 1969.

11) Maguire, Charles A. and Associates, Regional Water System Study, Prepared for the Connecticut River Estuary Regional Planning Agency, April 1972.

SECTION III

COORDINATION

5. Project Coordination

The study effort provided for direct participation and coordination by Federal, State and local agencies as well as interested conservation and citizen groups. To achieve full participation by all interested, a series of formal public meetings, progress meetings and informal informational meetings was employed.

All of these meetings and extensive letter communications furnished the principal means of contact with the public. Appendix H describes these meetings in detail including summaries of the statements made.

A. Public Meetings

A total of 13 formal public meetings were held within New England during the studies. Seven meetings were held at the outset of the NEWS investigations in May and June 1967. These meetings were held in all six New England States at Springfield and Waltham, Massachusetts; Portland, Maine; Concord, New Hampshire; Montpelier, Vermont; Bloomfield, Connecticut; and Providence, Rhode Island. At these meetings the background leading to the Northeastern United States Water Supply Study and the studies' objectives described. Citizen input was solicited and questions on the study were answered.

During December 1971 and January 1972, a series of four formulation stage public meetings were held in Needham, Woburn, Orange, and Longmeadow, Massachusetts. These meetings were designed to broaden public participation in the open planning process by describing on-going studies and receiving audience input. Some people spoke in favor of the plans presented. Others thought that we should concentrate on reducing demand instead of diverting more water to Eastern Massachusetts.

In July 1972 two late stage public meetings were held in Waltham and Orange, Massachusetts. At these meetings, the results of the NEWS investigations were described. Advantages and shortcomings of the

alternative proposals for meeting short-range water supply needs were outlined and discussed. Audience input at these meetings ranged from approval of the projects described as most advantageous to requests for modification of various elements and in some cases opposition to any of the diversions proposed.

A court stenographer was employed to provide permanent records of all three series of meetings. An abstract of the results of these meetings is given in Appendix H.

B. Progress Meetings

Since the initiation of these studies, a determined effort has been made to inform the public of the work's progress. Nine progress meetings were held in the Boston Metropolitan area, generally at Waltham, Massachusetts, the first held on 7 May 1970, with the latest held on 7 June 1972. Attendance at these meetings generally averaged about 50 people, with attendees representing Federal and State Agencies, conservation commissions, the Audubon Society, sportsmen groups, and interested citizens. Progress on various elements of the NEWS study was described by the study team. In an informal atmosphere, questions, answers and opinions were interchanged between the study team and audience. Input gained at these meetings served to guide the direction of the study and the final recommendations.

C. Information Meetings

In addition to the progress meetings, four informal information meetings were held within the Millers River Basin. These meetings were held in Athol, Massachusetts on 21 October 1971 and 4 January 1972, and in Winchendon, Massachusetts on 2 March 1972, and in Athol, Massachusetts on 8 May 1972. These meetings were held at the request of local government or citizens' groups and offered a further opportunity for public understanding of the study and public participation in its conduct.

D. Citizens' Participation Board

At the November progress meeting, a number of citizens stated a desire for formation of a "Citizens' Participation Board." The purpose of this Board was to act as an ombudsman for citizens in the watershed from which diversion of water was contemplated. Initiated in December 1971, this Board has worked with members of the study team to insure that views of the watershed citizens were known throughout the conduct of the study.

SECTION IV

PHYSIOGRAPHY - CONNECTICUT RIVER BASIN

6. Location

The Connecticut River Basin, shown on Plate No. 3, encompasses an area of about 11,250 square miles, of which 114 square miles are located in the Province of Quebec, Canada. The mainstem of the river traverses a length of more than 400 miles from the Canadian border to the tidal waters of Long Island Sound. The basin has a maximum width of 60 miles and includes land in 4 States. Land area in these States is distributed as follows: in New Hampshire, 3,047 square miles or about 28%; in the State of Vermont, approximately 3,928 square miles or about 35% of the drainage area; in the State of Massachusetts, about 2,726 square miles or approximately 24% of the basin area; and in the State of Connecticut, 1,436 square miles or about 13% of the study area.

The estuary is bounded by the mouth of the river at Saybrook. Here the river ends as it enters Long Island Sound. Throughout its entire length, the Connecticut River displays a rather unique profile, augmented along the way by many tributary streams. More than 200 dams, each controlling more than 50 square miles of drainage area, are harbored within the basin. Most of these dams are used for production of electric energy or for other manufacturing purposes. Several are used as municipal water supply reservoirs. Included are 16 flood control reservoirs constructed by the Corps, representing approximately 60% of a yet to be completed comprehensive flood control system. Many native lakes and ponds are available. For example, within New Hampshire alone, there are 199 of these ponds of over 10 acres, the largest of which is Lake Sunapee with 4,085 acres, followed by the First Connecticut Lake with 2,087 acres.

7. Natural Resources

A. Surface - Land Forms Elevation

The Connecticut River Basin is located within the Appalachian highlands of North America, which extends from Newfoundland to Alabama. The basin is entirely within the New England physiographic province which is further divided into sections, several of which have portions within the Connecticut River Basin.

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Within the northeastern mountain delineation, one finds elevations varying from 1,000 to 4,000 feet above mean sea level with a few peaks up to 5,000 feet or more. Mount Washington, in the White Mountain range, has an elevation of 6,288 feet. In the New England upland section, elevations range from sea level in southern Connecticut to about 1,000 feet in the middle portion. Some hills rise to 2,000 feet, and there are a few peaks which rise above 3,000 feet. The Connecticut Valley lowland, which makes up the Connecticut and Massachusetts portion of the basin, has elevations which range from sea level between Hartford and Middletown to ridge crest 500 to more than 1,000 feet above sea level.

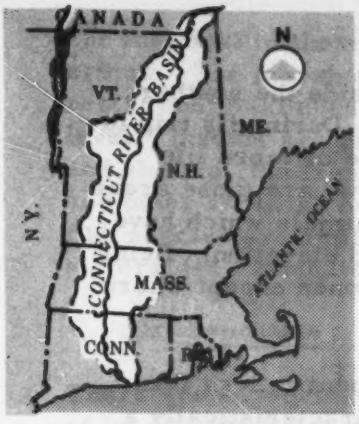
B. Geology - Soil - Mineral Resources

The northeastern mountains and the New England upland sections are underlain by crystalline bedrock which varies widely with regard to structure and rock type. These two land resources are underlain by metamorphic and igneous bedrock as well. The dominant rocks are gneiss, schist, phyllite, slate, and quartzite.

Known occurrences of minerals are numerous. Most of these minerals are located in areas that are not conducive for exploitation, at least under present economic technical conditions. However, there are important exceptions to this; namely, beryl, mica, gems, abrasive, feldspar, copper and dimension stone. Economically far more important are the triassic trap rock which forms an important source of crushed rock. It is used in a number of different projects and as an aggregate for concrete. Also of importance are the blue clays which are used for the manufacture of bricks and drain tile. Sand and gravel deposits are plentiful in the valley, particularly below Turners Falls and south to Middletown, Connecticut.

Soil condition and physiography of the area have a marked influence on its use. The most intensive agriculture in the basin is in the Connecticut Valley lowland. The silty and fine sandy soils on the high, level flood plains and terraces along the Connecticut River are largely devoted to the production of potatoes, nursery stock, and vegetables. The more sandy and gravelly soils on the till from triassic shales and sandstones are widely used for production of tobacco, potatoes, vegetable crops, and forage for dairy herds.

The New England upland is less suited to intensive agriculture than the Connecticut Valley lowland. Much of the present agriculture in this area is based on the bottom and terraced lands of the Connecticut River and its major tributaries included.



CANADA

VT.

N

N.H.

MAINE

VT

N.H.

Upper Ammonoosuc R.

Moose R.

Passumpsic R.

St. Johnsbury

Ammonoosuc R.

Woodsville

Ompompanoosuc R.

White R.

Ottauquechee R.

Mascoma R.

CONNECTICUT RIVER

Hartland

Black R.

Springfield

West R.

Brattleboro

Deerfield R.

VT.

MASS.

N.H.

MASS.

Greenfield

Millers R.

Athol

Ware R.

Quaboag R.

Westfield R.

Chicopee R.

MASS.

CONN.

Farmington R.

New Britain

New Haven

New London

LONG ISLAND SOUND

NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

CONNECTICUT RIVER BASIN

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

SCALE IN MILES

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PLATE 3

C. Biological Productivity

The Connecticut River Basin extends from just inside the southern border of Canada southerly to Long Island Sound. During its trip to the ocean, water in the basin will pass through one or more life zones. The life zones, more fully described below, are those areas which contain a specialized system of plant and animals which have evolved through the years by means of climate and elevation. Being entities, there is little crossover between these zones except where they meet.

1) Sub-Arctic Zone - This type of environment is less than 1/10 of 1% of the total area of the basin. It is characteristically a treeless area of heath and bogs. Ground ferns, hardy members of the buttercup family, stunted willows and lichens like reindeer moss are the plants commonly associated with this type of area. The animals normally associated with this life zone are absent with the exception of insects notably a single species of butterfly found on Mt. Washington.

2) Boreal Forest - At lower elevations we find the taiga or boreal forest, characterized by spruce - fir associations. Snowy owls, Canadian lynx, and moose are the most striking animals associated with this life zone. Less remarkable but most often encountered are the varying hares, red squirrels, and Canada jays. Brook trout, a type of char, are found in the streams.

3) Temperate Hardwood Forest - The major portion of the basin is characteristically the hemlock - deciduous hardwood forests found in the central and lower portion of the basin. Maple, beech, hemlock, and pines are the dominant tree types in the area. In the woods of the lowest portion of this zone, oaks and hickory are frequently encountered. White tailed deer, black bear, gray fox and gray squirrel and cotton tail rabbits are characteristic animals of these forests.

4) Estuarine Zone - The lower Connecticut River Basin is influenced by the proximity to the marine environment, with tidal waters extending upstream to the vicinity of Hartford, Connecticut, a river distance of approximately 60 statute miles. Associated with this marine affected climate is a community of flora and fauna adapted ecologically.

As influenced by the tide, the streamside meadows and woodlands give way to tidal salt marshes. The grasses and shrubs found here

are identical to those found north and south along the coastal estuarines. The marsh animals are characterized by their ability to resist continual changes in salinity and periodic fluctuation in water level. Insects are largely replaced by the crustaceans such as crabs and shrimp, the freshwater clam gives way to the mussels, clams and other shellfish normally associated with estuaries. Freshwater fish species are replaced by species of the coastal waters such as silversides, varigated minnows, tomcods, and flounders.

D. Land Use

There are approximately 169,400 acres of water and 6,957,600 acres of land in the United States portion of the Connecticut River Basin study area. The distribution is as follows: 79 percent in forests; 9 percent in crop lands; 4 percent in pastures; 4 percent in urban and built-up areas; 4 percent carried in the "other" category. To the year 2020 this land use is projected to grow in the direction of urban and as follows: 79 percent will remain in forests; 10 percent will become urban and built-up; only 2 percent remaining in crop lands; 1 percent in pastures; and 8 percent in the "other" category.

Presently, over 85 percent of the land is privately owned by individuals or corporations, but the remainder is publicly owned. Farmers own about 1.7 million acres. Other private owners own about 4.5 million acres including that land in urban and built-up areas. Public ownership principally forested land consists of about 306,600 acres of Federal land in the Green Mountain and White Mountain National Forests and 410,000 acres of State, County and municipal lands. Some 17,000 acres of Federal land is also found in Corps of Engineers reservoir projects.

8. Climate

A. General

In addition to normal variation with latitude, the climate of the basin varies to a marked extent with differences in elevation. The Connecticut River Basin lies in the realm of prevailing westerlies, and as such, comes under the influence of cyclonic storms which traverse from the west and southwest. The southern part of the basin is also influenced by warm, moisture laden anti-cyclonic storms. In the winter months, highs from Canada bring arctic air into the basin. Precipitation is moderate and well distributed on an average annual

basis. However, monthly rainfall records show great variety from year to year. Individual storms rarely affect the basin in its entirety owing to the elongated character of the watershed. Generally, west to southwest airflow brings the hot dry weather which is responsible for occasional summer drought.

B. Precipitation

Mean annual precipitation over the entire basin averages 43 inches of water and ranges from 36 inches to 74 inches. Run-off, that portion of precipitation left after evaporation and transpiration, as well as deep underground flow to the sea, averaged about one-half or approximately 23 inches.

C. Temperature

The mean annual temperature for the basin is about 45°. It varies from 38° at First Connecticut Lake to 49° at Westbrook, Connecticut, near the mouth of the river. Average monthly temperatures vary widely throughout the year from between 63° and 74° in July and August to between 11° and 30° in January and February. Average daily temperatures range from occasional highs in the 100's to infrequent lows in the minus 40's in the northern portion and in the minus 20's in the southern portion. Frost-free periods range from 180 days in southern Connecticut to about 100 days at northern points.

D. Storms

There are three general types of storms that cause precipitation over the basin; namely, continental, coastal, and frontal storms. Continental storms originate over the western or central portion of the United States. They generally move easterly or northeasterly in direction and may be rapidly moving intense cyclones or the stationary frontal type. They are not limited to any season or month, but follow one another at more or less regular intervals with varying intensities throughout the year. Tropical hurricanes, the most severe of the coastal storms originate in the South Atlantic or Western Carribean Sea. They usually move in a westerly direction, recurving to a more northerly path near the mainland and then northeast approaching New England. Although the general path is to the south and east of New England, they may be drawn over this area by continental cyclonic disturbances, or deflected by a large slow anti-cyclone center, sometimes referred to as a blocking high and generally located to the east of New England. Hurricanes have occurred during the late summer or fall

months with a higher incidence in August and September. Extra-tropical coastal storms generally originate near the Middle Atlantic States. They travel northward along the coastline and frequently occur during the autumn, winter and spring months.

9. Water

A. General

The Connecticut River mainstem follows a general southerly course along the approximate center line of its watershed for about 404 miles to its mouth on Long Island Sound at Saybrook, Connecticut. The lower 60-mile reach of the river is tidal having a mean tidal range during low river stages of 3.4 feet at the mouth and about 1.2 feet at Hartford, some 52 miles upstream of the mouth.

B. Flow and Fall

The Connecticut River mainstem in its total length has a total fall of about 2,650 feet. In the initial 30 miles from its origin at the Canadian border, the river accomplishes half of this total fall. From this point, approximately at the First Connecticut Lake, and proceeding to tide-water at Hartford, Connecticut, a distance of about 360 miles, the river accomplishes a fall of about 1,640 feet. In the lower reaches of the river, the average annual flow is approximately 16,000 cubic feet per second, or equivalent to 23 inches of run-off. A review of hydrologic records in the valley indicates that during low flow periods, flows on some of the tributaries dropped to less than .1 csm, and on an average, approximately .15 csm. This is contrasted to the average annual figure of 1.6 csm, that represents nearly 1 million gallons a day per square mile of drainage area. It can be seen, therefore, that summer low flows contrast markedly with average flows and represent about 1/10 of the yearly average flow.

C. Reservoirs - Lakes - Ponds

The Connecticut River is blessed with numerous bodies of water, some natural and others man-made. For example, there are 172 bodies of water that range in size from 100 to 499 acres. Of this amount, 29 are used for water supply purposes and 143 are used for non-water supply purposes.

D. Estuary

The shell fisheries of the Connecticut River estuary are not extensive nor do they support any significantly important commercial enterprise. Oyster operators do a small amount of commercial oystering on beds near the mouth of the river, however, the harvesting of soft-shell clams and hard clams has not been important in recent years. The major value of the estuary from an ecological viewpoint is that within the estuary the basic formation of the food chain and life cycle of estuarine dependent species occurs.

The lower river thrives as a recreational boating center. Power boats, sail boats, water skiers, skim over its waters, while its shores provide safe harbor for small and large craft. Marina development is steadily creeping up the river, and in most cases is taking place on tidal wetlands, a vital resource to the fisheries.

E. Wetlands

The Connecticut Valley is a migratory route for considerable numbers of waterfowl. Many of these birds pass through without tarrying. Principal waterfowl habitat in the upper basin is the main stem of the river; the Ox Bow Ponds, primarily in New Hampshire between Stratford and Lancaster; the numerous natural lakes, ponds, and bogs; and innumerable beaver flowages.

There are a number of excellent marshes near the mouth of the river in the Connecticut mainstem with heavy waterfowl usage. Great Island, Ragged Rock Creek, Lord's Cove, Selden Neck, North Cove, Essex, Cromwell Meadows, and South Windsor marshes are waterfowl habitat areas receiving heaviest use.

F. Groundwater

A reconnaissance of the groundwater resource of the Connecticut River Basin has been performed by the U. S. Geological Survey of the Department of the Interior. The report summarized that groundwater is available in large quantities in some of the larger valleys from sands and gravels of glacial-fluvial and alluvial origin. Groundwater recharge is about equal to 1 million gallons per square mile in unconsolidated sandy sediment. Where earth material is underlain in large part by consolidated rock, this drops to 1/3 MGD per square mile. The total quantity of groundwater available from the basin is perhaps more than 1 billion gallons per day. The more generous amounts are located in the upper watershed where demands are lightest.

SECTION V

ECONOMIC DEVELOPMENT

10. General

This section is drawn from data contained in Appendix A and describes the past and projected changes in the economic growth of the source area within the Connecticut River Basin and the service area, the Boston Metropolitan Region. For purposes of this analysis, the source area is considered to be Franklin County, Massachusetts. This choice was made since the Northfield Mountain Project lies within its boundaries and any impacts caused by the project would be expected to be largest here.

A discussion of the historical forces which have been influential in shaping both regions' present day economic characteristics is given. This discussion then sets the stage for the analysis of future economic growth for both the Franklin County and Boston Economic Areas.

11. Measures of Economic Activity

Economic changes can be measured by a set of interrelated variables; namely, population, labor force employment, personal income and net output. These indicators express in economic terms the need for water resource development in an area. Especially important are the numbers of people projected to live in an area and any expected changes in industrial activity.

National projections of the overall economy for both regions were made in terms of benchmark aggregates such as gross national product, population, personal income and employment. From these summary measures were derived national totals of the economic series to be projected for local areas. Implicit in this procedure is the fact that national forces clearly dominate economic development throughout the nation. Because of the lack of gross area product data which could be compared to gross national product data, other indications of economic activity at the regional level are utilized. Employment data available in detail at the regional level are used to indicate changes in industrial activity and total personal income provides an overall measure of regional economic growth.

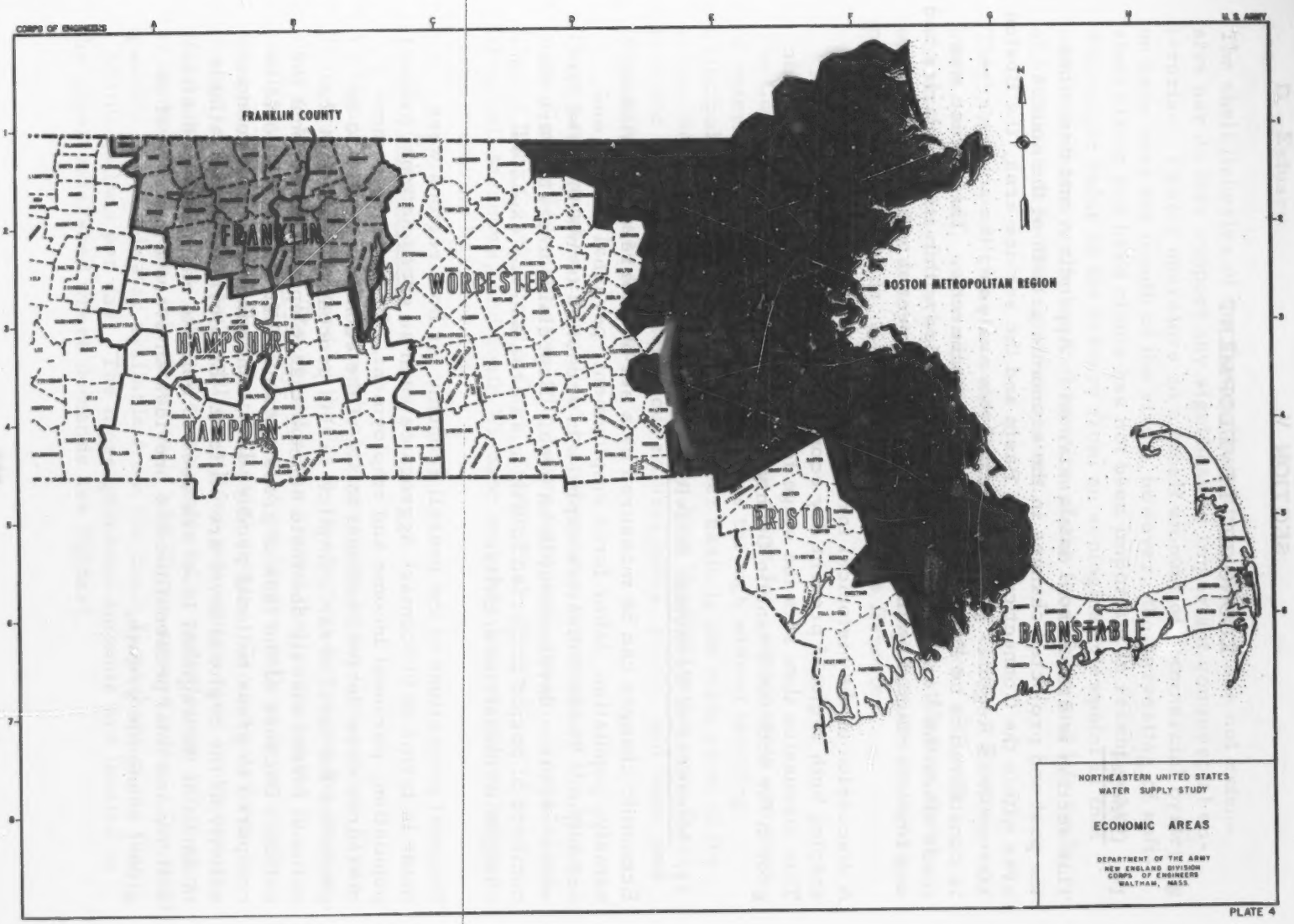
CORPS OF ENGINEERS
U.S. ARMY
FRANKLIN COUNTY
FRANKLIN
WORCESTER
HAMPSHIRE
HAMPDEN
BOSTON METROPOLITAN REGION
BRISTOL
BARNSTABLE
N
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
ECONOMIC AREAS
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 4

12. Past Trends in Economic Growth

Franklin County is divided almost in half by the Connecticut River. West of the Connecticut, the rugged terrain and well defined valleys, especially in the northwestern portion along the famed Mohawk Trail, provide some of the most beautiful scenery and panoramic views in Massachusetts. East of the river, the elevations are more moderate and the terrain mostly covered with rolling hills. Here, the Millers River, a tributary of the Connecticut, also provides tourists with additional recreation opportunities. Five ski areas and facilities for boating, camping, hunting, picnicking, and swimming in various combinations at several state forests and parks make the County a desirable year-round vacation area. A large section of Quabbin Reservoir, which supplies many of the municipalities of Metropolitan Boston, is located in the southeast corner of the County.

Beginning with the earliest settlements in the late 1600's, agriculture was the major industry with areas too steep for plowing used for sheep grazing. The plains yielded crops of wheat, tobacco, and corn without too much difficulty, and by the late 1800's, the County had grown to be the largest potato producing area in Massachusetts.

The abundance of water was a prime factor in the early development of hydro-electric power in the region. Later, the same abundance of water was a prime factor for the siting of a nuclear power plant of the Yankee Atomic Electric Company in the town of Rowe.

At present, Franklin County is a predominantly rural area with several industrialized areas concentrated in the central and eastern sectors. In many ways, the County has more in common with southern Vermont than with the remainder of Massachusetts. It is a slow growth region with low population density, has no large metropolitan area, and its labor force, a product of the economic structure, is composed of mainly blue collar workers and few white collar workers.

The only higher educational facility located in the County is Greenfield Community College. Deerfield Academy, one of the oldest boarding schools in the country, Englebrook, a preparatory school for boys, and Bement, coeducational, constitute the major industry for the town of Deerfield. Located in surrounding towns, however, are several major schools of higher learning including the University of Massachusetts, Amherst College, and Hampshire College in Amherst, Smith and Northampton Commercial College in Northampton, Mount Holyoke College in South Hadley, Williams College in Williamstown, the State College at North Adams, and Mount Wachusett Community College in Gardner.

Among the County's primarily basic or export industries, manufacturing and agriculture stand out as being the most significant. Manufacturing now, as it has throughout the early 1900's, contributes the most to the economy of the region as measured by the number of persons employed, the next most important sector being services.

In 1963, the seven largest manufacturing groups, in order of importance as employers, were non-electrical machinery, paper and allied products, fabricated metal products, textile mill products, food and kindred products, lumber and wood products, and printing and publishing. The manufacture of non-electrical machinery and fabricated metal products alone accounts for about one-half of total manufacturing employment.

In 1970, the major water using manufacturing industries in the County; namely, food and kindred products, textile mill products, paper and allied products, employed 2,256 persons. This represented approximately 30 percent of manufacturing employment and 10 percent of total employment in the County for that year. Total employment in these industries has remained relatively stable between 1956 and 1970. Hidden within these totals, however, are substantial declines in textiles and increases in food and kindred products.

The only remaining natural resource industries are food processing and lumber products manufacture which together provided 8.6 percent of manufacturing employment in 1963. The paper industry originally located in the County because of locational factors such as closeness to markets, low cost labor and low transport costs. These advantages no longer exist today. The remaining manufacturing industries, not dependent on natural resources, are producing products which can be described as high-valued and lightweight.

As for agriculture, once Franklin County's most thriving industry, it is today the most rapidly declining sector in terms of employment. The primary cause, as elsewhere in the Connecticut River Valley, is the rising value of farm land in alternative uses resulting from expanding urbanization with its high taxes and wage levels.

On the other hand, the service area, the Boston Metropolitan Area, was one of the earliest settled areas of the United States and has for many years experienced a high level of urbanization. Only in recent years, however, have the outer most towns of the area begun to feel the urban pressures. Like the Franklin County Economic Area, farming was the principal occupation of early settlers and the abundance of water power was a vital factor in the industrialization of the area.

However, the Boston Area also has good marine resources and soon became one of the most important commercial and trade centers on the east coast.

Today, the Boston Metropolitan Area is geographically and economically the center of the largest employment and population cluster in New England. This cluster is the northern terminus of "megalopolis," the Atlantic coastal strip between Washington and Boston, in which live approximately one-fifth of the United States' population. Boston, the central city, is the Massachusetts State Capital, the most populous city in New England, and the center of the eighth largest SMSA in the country. While only secondarily a manufacturing center, the city's primary function in the area is as a trade and finance center. In the economic area as a whole, however, manufacturing has the largest share of total employment, followed by the service industries. Specialization occurs in miscellaneous manufacturing, electrical machinery, textiles, professional services, trade and construction. In recent years, the Boston area has experienced a remarkable growth in technologically-oriented industries which have located here in response to, or as spinoffs of, the concentration of advanced education and research facilities.

13. Projected Economic Growth

Projections are based on extensions of past relationships believed to have future relevance for the measures being projected. Underlying these extensions of past relationships are assumptions that make the projections conditional forecasts. For instance, it is assumed that the Federal government will implement policies needed to maintain relatively full employment and avoid prolonged levels of inflation and that the economy will be free of the distorting effects of a major military conflict during the 50-year projections interval. It is assumed that water will play the same role in stimulating or depressing economic growth in the future as it has in the past.

In general, the examined historical data and projections derived indicate that both the Franklin County and Boston Metropolitan Area economies will continue to expand and prosper in the period 1970 - 2020. The projected rates of expansion for the two regions, however, differ markedly. In the process of expansion, both areas will continue to export valuable services and/or manufactured goods beyond their boundaries. Changes within and around the area's various economic sectors are, of course, inevitable and will play a dominant role in determining

the region's growth paths. Population, urbanization, employment, personal income and the nature and co-position of the industrial and business mix of the economies will all be of special relevance to the diverse water resource problems and needs of the two areas.

Population in the Franklin County Economic Area is expected to increase from 58,853 in 1970 by a factor of 1.4, to 80,000 people by the year 2020, although a decline is anticipated in relation to the total population of New England from about 0.5 percent to about 0.4 percent of the six-state figure. At the same time, population in the Boston Metropolitan Area is expected to increase from 3,652,000 in 1970 by a factor of 1.7 to 6,126,000 by the year 2020. Here again, a decline is anticipated in relation to the total population of New England from 31.3 percent to 30.9 percent of the six-state figure.

Total personal income in the Franklin County Economic Area is expected to rise by a factor of 4.9 by the end of the projection period. Since the area's population will be 1.35 times greater, per capita personal income will rise about 3.6 times present levels. At the same time, total personal income in the Boston Metropolitan Area is projected to increase by a factor of 6.3. Thus, per capita personal income in the Boston Area will increase close to 3.7 over the projection period.

The manufacturing sectors in both the Franklin County Economic Area and the Boston Metropolitan Area are projected to decline relative to the non-manufacturing sectors in importance as sources of employment. Employment in Franklin County's manufacturing industries is expected to drop from 33 percent of total employment in 1970 to roughly 25 percent by the year 2020. In the Boston Area, manufacturing employment as a percentage of total employment is projected to decline from 29 percent to 20 percent over the projection interval. By the year 2020, there will be more employees in non-manufacturing jobs than in manufacturing positions in both areas. Employment in the services is expected to increase 93 percent by the year 2020 in Franklin County and 153 percent in the Boston Metropolitan Area. Expanding population and rising personal income indicate further advances for urban services such as finance, insurance, real estate and medicine and health in the Boston Metropolitan Area. Thus, the projections of manufacturing and non-manufacturing employment show the structural shifts which both economies are expected to experience.

The major water using industries in both the source and service area include food and kindred products, textile mill products, chemical and allied products, petroleum refining and primary metals industries. In

the Boston Area, employment in food, textiles, and petroleum are projected to decrease greatly while employment in the chemical and paper industries is expected to more than double by 2020. Projections specific to Franklin County's water using industry are not available. However, available past employment data as shown in Table A-9 indicate that total future employment in these industries can be expected to remain stable during the projection interval.

In 1970, Franklin County had a total of about 2,300 people employed in the water using industries, while the Boston Area had a total of about 171,000 employed. Thus, the Boston Region industries employed about seventy-five times as many people as in Franklin County. In both areas, the economic production per employee is projected to dramatically increase. Therefore, the economic production in dollars for the water using industries in both areas is actually increasing. In absolute terms, however, the production of the Boston Region far exceeds Franklin County.

SECTION VI

THE WATER SUPPLY SETTING

13. General

A. Sixties Drought

As recognized in the NEWS Legislation, natural departures from normal precipitation and runoff conditions can have regional impacts on the social well-being of a large segment of the nation's population.

The long-term normal rainfall in southeastern New England is about 42 inches per year. This "normal" condition is actually the average of many high and low rainfall years. When rainfall is below average for a period of time, the area experiences a drought. The recent drought of the sixties in southeastern New England, for its duration, was the greatest ever experienced in the region based on over 200 years of rainfall record.

Because of the severity of this drought, many water supply systems were required to re-evaluate the dependable yield which their facilities could be relied on to produce. For example, the Metropolitan District Commission which, based on previous drought conditions, had estimated available sources at 330 million gallons per day (mgd) revised their dependable yield figure downward to 300 mgd.

The sixties' drought which began in 1961 when precipitation and water levels fell below normal, ultimately through its duration, directly affected the water use patterns of more than 20 million people. In 1965 alone, drought related water shortages and associated problems were severe enough to warrant emergency actions by local, state and Federal agencies. Within Massachusetts, more than 50 cities and towns imposed restrictions on water use.

B. Water Supply Agency Action

During and following the drought, a number of communities and regional planning agencies conducted engineering studies to determine methods for augmenting their existing supplies. In many cases, new supplies have been developed by the communities which would allow them to meet future supply needs. Investigations conducted by NEWS in the southeastern New England region, however, indicate that even

with the actions undertaken by local authorities, additional supplies must be made available.

It is anticipated that as water requirements increase and local water resources are fully developed, particularly in urban areas, many municipal systems will likely join some of the major systems, such as the Metropolitan District Commission (MDC) and increase the regional character of these systems. A description of the MDC system is given in the following paragraphs.

14. Existing Regional System - Metropolitan District Commission - (Boston)

The Metropolitan District Commission (Boston) is the largest regional system within New England. At present, this system supplies either wholly or partially the water supply needs of 42 communities within the Commonwealth of Massachusetts. Consumers of the serviced population number about two million or fully 37 percent of the Commonwealth's 1970 population.

Existing dependable yield of the system is estimated to be 300 mgd. Average daily water consumption furnished by the system in 1971 was 322 million gallons per day (thus the system is outstripping available supply) of which 273 mgd was delivered to municipalities which rely exclusively upon the MDC as their only supply source. A plan of the communities is shown on Plate No. 5.

The MDC relies upon surface water as its supply source. Three major reservoirs: Quabbin, Wachusett and Sudbury impound flow from tributaries of both the Connecticut and Merrimack River Basins. A plan showing the location of these reservoirs and interconnecting aqueducts is shown on Plate No. 6.

The Quabbin Reservoir, located in the center of Worcester County, is the backbone of the MDC system. It impounds the runoff from 186 square miles of the Swift River Watershed and flow diverted from 98 square miles of the Ware River Watershed, both tributaries of the Connecticut River. It has a capacity of 412 billion gallons at full reservoir elevation and is approximately 18 miles long.

The water from Quabbin Reservoir flows through the Quabbin Aqueduct for a distance of 24.6 miles to the upper end of Wachusett Reservoir in West Boylston. This aqueduct, which is "horseshoe" shaped, is excavated through solid rock and line with concrete. Provisions have been made at the Ware River Intake Works at Coldbrook to divert the

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flood flows from approximately 98 square miles of the Ware River Watershed into the aqueduct for storage in either the Quabbin Reservoir or the Wachusett Reservoir. Under ordinary circumstances, the water is diverted directly to the Quabbin Reservoir for storage and then is drawn back into the Wachusett Reservoir as occasion requires.

The Wachusett Reservoir on the Nashua River, a tributary of the Merrimack River, above Clinton, was the principal reservoir of the MDC system prior to the construction of Quabbin Reservoir. It has a watershed of 107.7 square miles and a capacity of 65 billion gallons. It is approximately 8.4 miles long with a surface area of 6.5 square miles.

The water has two means of conveyance from Wachusett Reservoir -- the Wachusett Aqueduct and the recently completed Wachusett - Marlborough tunnel. The Wachusett Aqueduct consists of a rock tunnel section 2 miles in length, a brick and masonry conduit, "horseshoe" shaped, 7 miles in length and an open channel section of 20 feet wide at the bottom and 3 miles in length. The open channel section terminates in the Sudbury Reservoir in Southborough.

The major portion of the water supplied by the Wachusett Aqueduct is diverted at a diversion dam on the open channel section of the aqueduct in Marlborough into the Hultman Aqueduct. The remaining water flows into the Sudbury Reservoir.

The Sudbury Reservoir is situated on the north branch of the Sudbury River and impounds the runoff of approximately 22 square miles of watershed; has a storage capacity of approximately 7 billion gallons.

During summer months, large quantities of water flow from this reservoir through the Sudbury Aqueduct to the Chestnut Hill Reservoir in Brighton. From there, it is pumped into the distribution system.

The new Wachusett-Marlborough Aqueduct is a deep rock concrete lined tunnel, 8.0 miles long. It extends from the Wachusett Reservoir to the Hultman Aqueduct intake structure. The major portion of the water supply requirements of the Metropolitan Water District is delivered through this aqueduct to the Hultman Aqueduct and thence to the Norumbega and Weston distribution reservoirs.

The Hultman Aqueduct begins at the previously mentioned diversion dam located on the open channel section of the Wachusett Aqueduct. It extends from this point 22.7 miles in an easterly direction to the Chestnut Hill Reservoir and pumping stations. This aqueduct consists of cut and cover concrete conduit and a section of hardrock tunnel. At the

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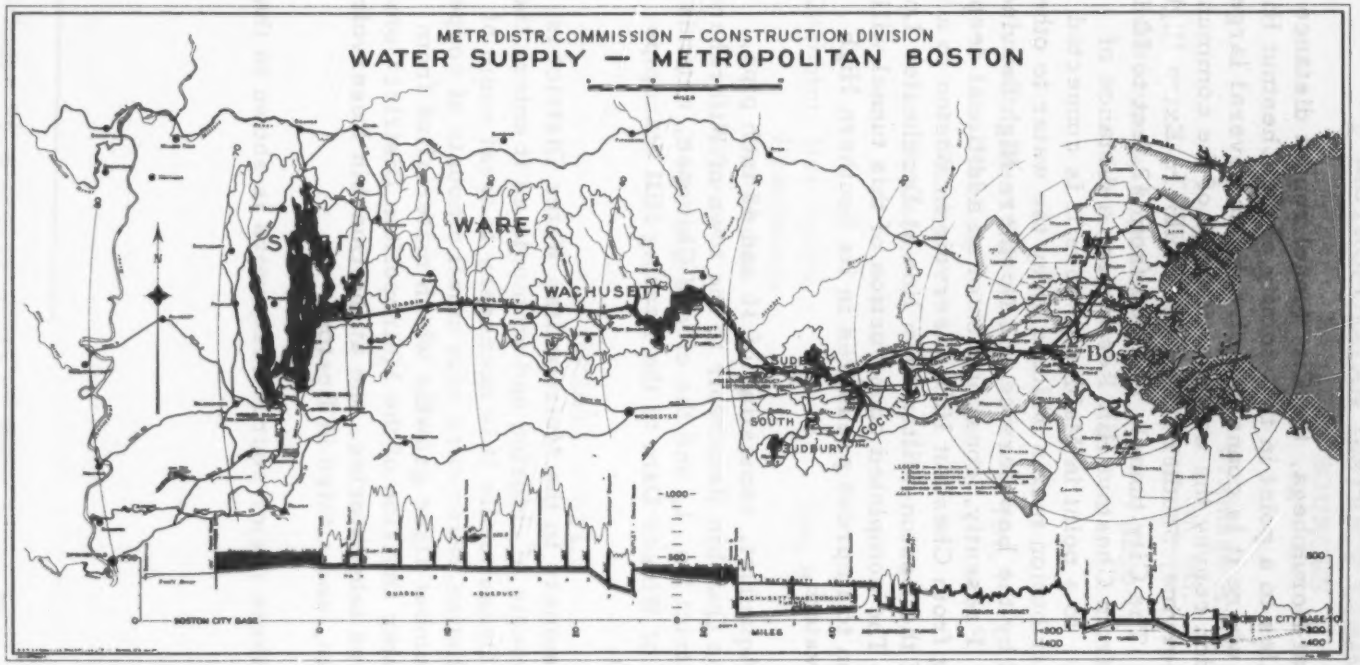

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

METROPOLITAN DISTRICT COMMISSION
EXISTING WATER SUPPLY SYSTEM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 5

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Sudbury Dam, it is interconnected to the Weston Aqueduct which is a cut and cover conduit extending to the low pressure service Weston Reservoir.

From an intake shaft at Norumbega, the City tunnel runs a distance of approximately 5 miles to a point in the vicinity of the Chestnut Hill Reservoir in Boston, where it is connected directly to several large distribution mains which convey the water to several of the communities serviced by the Low Service, Southern High and Southern Extra High distribution systems. The City tunnel, reduced from 12 feet to 10 feet in diameter, extends from Chestnut Hill Reservoir, a distance of approximately 7 miles, to a point in Malden, where it is connected directly into large distribution mains which convey the water to other communities serviced by the Low Service and Northern High Service distribution systems. Presently, construction of an additional deep rock tunnel, extending from Chestnut Hill Reservoir in Boston to a point in the vicinity of the Boston-Milton town line at Dorchester Lower Mills, is under way. The completed construction of this tunnel will enable the Commission to improve pressures in its Southern High Service distribution system.

The Chicopee Valley Aqueduct, consisting of 36 and 48 inch pipe, conveys water from the Quabbin Reservoir to the town of Wilbraham, South Hadley Fire District No. 1, and the city of Chicopee, extends from the outlet works of Winsor Dam to the Keating Hill Standpipe of the city of Chicopee.

Water supplied to consumers in the Metropolitan Water District is treated with small amounts of chlorine and ammonia as it enters the distribution system. Occasionally it is necessary to treat some of the storage and distribution reservoirs with small amounts of copper sulphate in order to combat algae growths which materialize from time to time. The Water Division of the Metropolitan District Commission maintains three laboratories, one at the Quabbin Reservoir, another in Framingham, and a third in Boston.

Pertinent data on the three major source reservoirs is shown in the following table:

TABLE 8

METROPOLITAN DISTRICT COMMISSION SYSTEM SOURCES

	Location	Drainage Area Sq. Mi.	Storage Capacity (mg)
Sudbury:	Southborough Marlborough	22.0	7,000
Wachusett:	West Boylston Sterling Clinton Boylston	107.7	65,000
Quabbin:	New Salem Petersham Hardwick Ware Belchertown	284.8 [1]	412,000
	TOTAL	414.5	484,000

[1] Includes 96.8 square miles of Ware River Watershed

15. Local Resource Potential

A. General

In estimating needs which might be required of the existing regional supply system (MDC), the role which locally available resources might play was investigated. The majority of new communities reported in this study as requiring connection to the regional system to meet future needs was the result of engineering studies[1] conducted by the Metropolitan Area Planning Council (MAPC). The MAPC comprises 98 municipalities in the Boston Metropolitan Region which include the majority of presently serviced MDC communities and the MDC's future short-range customers. In the following paragraphs, a brief summary of the MAPC engineering studies pertaining to local resource potential development is given.

"The purpose of this study is to identify and evaluate alternative water supply systems which may be developed to satisfy the water supply demands of the communities in the Council District through the year 1990. These systems would supplement the existing and potential local supply systems. The need for supplementing the existing supplies of most of the communities within the District was concluded from investigations conducted in conjunction with the 1969 Needs and Proposals report.

These investigations indicated that, of the 98 communities in the Council, only two communities had existing supplies capable of meeting projected 1990 demands, and only 17 communities outside of the communities served by the Metropolitan District Commission (MDC) reported potential supplies which, together with the existing supplies, could meet the 1990 demands.

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[1] Inventory of Water and Sewer Facilities, May 1967, Metropolitan Area Planning Council and Massachusetts Department of Commerce and Development, by Camp, Dresser & McKee, Consulting Engineers.

Projected Needs and Current Proposals for Water and Sewer Facilities, July 1969, Metropolitan Area Planning Council, by Camp, Dresser & McKee, Consulting Engineers.

Alternative Regional Water Supply Systems for the Boston Metropolitan Area, February 1971, Metropolitan Area Planning Council, by Camp, Dresser & McKee, Consulting Engineers.

The supplemental water systems discussed were developed along criteria and design guidelines chosen to be sufficiently generalized to permit use throughout the District, yet detailed enough to produce systems which were technically sound. The efficient development of a water supply system to meet the projected demands of the communities within the Council District will require further detailed studies of the most favorable alternatives presented in this study. All systems were developed without regard to institutional constraints. Particular emphasis was placed on the development of subdistrict systems which would serve a portion of the Council District through the utilization of local resources.

Five individual subdistricts were established as follows: the Charles River Subdistrict, the Concord River Subdistrict, the Ipswich River Subdistrict, the Neponset River Subdistrict, and the North River Subdistrict. A plan of the subdistricts is shown on Plate No. 7.

The supplemental needs of the individual communities were determined by comparing projected demands with the estimated safe yield of the existing and potential community supplies. Needs were assessed in accordance with the study policy that all local potential supplies were to be developed.

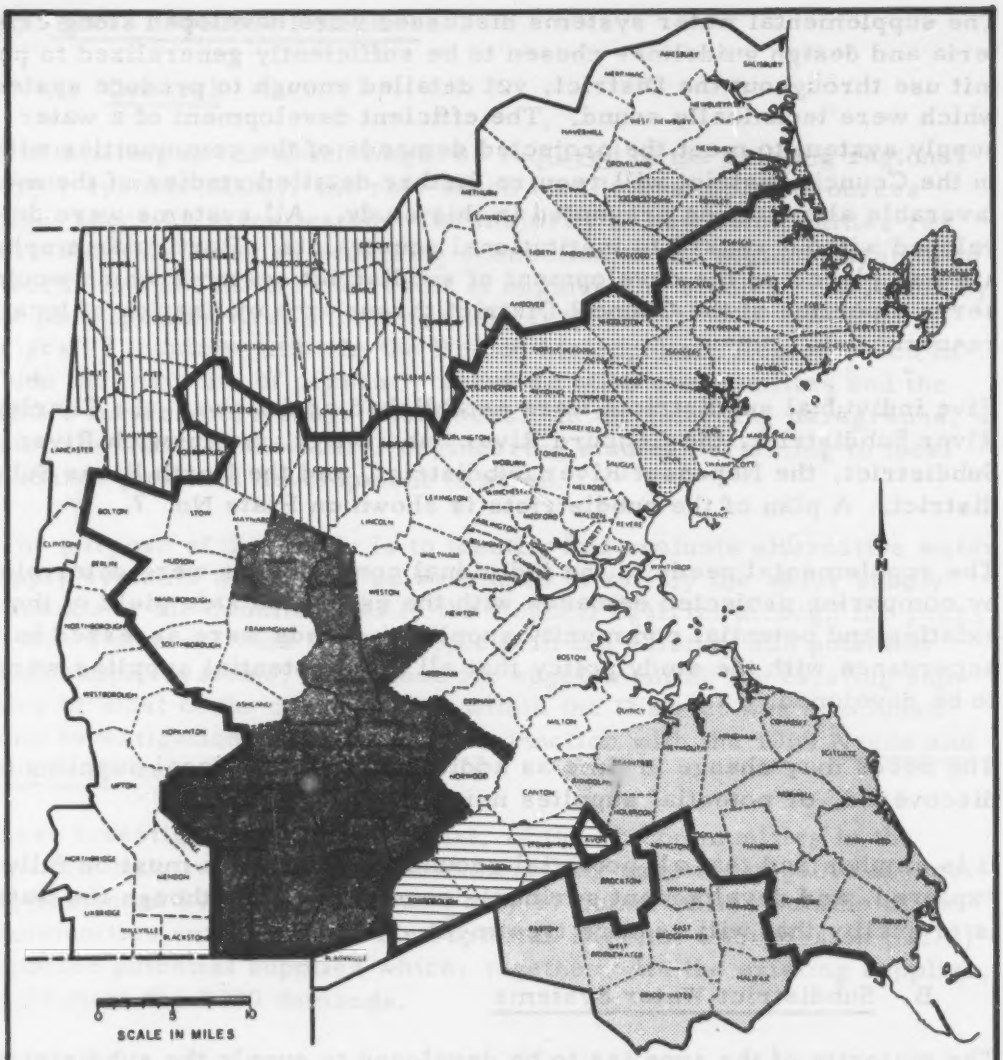
The needs may change in time as additional potential local supplies are discovered, or potential supplies must be abandoned.

It is emphasized that all potential groundwater sources must be fully explored, and development seriously considered even though the water is of quality that will require treatment.

B. Subdistrict Water Systems

The majority of the supplies to be developed to supply the subdistrict system will be surface supplies with either on or off stream reservoirs. It is imperative that before any of these alternatives are adopted, studies be conducted to investigate fully the environmental implications of these diversions.

1) Ipswich River Subdistrict: Two of the communities listed below have adequate existing supplies to meet their projected 1990 demands. An additional six communities have potential supplies which could adequately supplement their existing supplies through 1990. However, the potential supplies in five of the communities and the existing supplies in one of the communities make use of the Ipswich River.



LEGEND

- IPSWICH RIVER SUBDISTRICT
- CONCORD RIVER SUBDISTRICT
- CHARLES RIVER SUBDISTRICT
- NEPONSET RIVER SUBDISTRICT
- NORTH RIVER SUBDISTRICT

NOTE:

FROM ALTERNATIVE REGIONAL WATER SUPPLY SYSTEMS FOR THE BOSTON METROPOLITAN AREA, PREPARED FOR THE METROPOLITAN AREA PLANNING COUNCIL, BY CAMP, DRESSEN AND MCKEE, FEBRUARY 1971.

NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MAPC SUBDISTRICT AREAS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE-6

Beverly	Ipswich	Reading
Boxford*	Lynn	Rockport
Danvers	Lynnfield	Rowley*
Essex	Manchester	Salem
Georgetown*	Middleton	Topsfield
Gloucester	North Reading	Wenham
Hamilton	Peabody	Wilmington

*Not in Council District

The Ipswich River does not have the capacity to meet these collective demands. Unless the Ipswich River is supplemented, it will be unable to supply sufficient additional yield to even the communities which now pump from it. Through the construction of three new off-stream reservoirs, together with a diversion system from the Merrimack River, the Ipswich River can be developed to adequately supplement the existing and potential supplies of the communities in the Ipswich River Subdistrict. The Merrimack River is the only possible source which would permit diversion to the Ipswich during dry periods, thus reducing the size of the off-stream reservoirs required. The longer the period of diversion, the smaller the size of the reservoirs required to produce the same yield. Under present conditions, the diversion works would be located above the City of Lowell in the Town of Tyngsborough with water being transmitted about 17.6 miles to Lubber Brook in Wilmington, a tributary of the Ipswich. If the quality of the water in the Merrimack River was upgraded, the diversion works could be moved downstream to Andover, thus decreasing the length of the raw water transmission main.

Diversions would then be made from the Ipswich River at three general locations. At the first location, diversions would be made to a proposed 1800 million gallon (mg) regional reservoir in Lynnfield and to the existing Lynn and Peabody Reservoirs. The second diversion would occur downstream off Route 1 in Topsfield and would supply the proposed 1800 mg Topsfield reservoir. This new reservoir would be operated in conjunction with the existing facilities of the Salem and Beverly Water Supply Board. The third diversion would be located in Ipswich. Water would be pumped to the proposed 2800 mg Ipswich Reservoir.

2) Concord River Subdistrict: None of the MAPC communities in this subdistrict will be able to adequately meet their projected 1990 demands. However, the communities in the Concord River Subdistrict

can also be supplied by the Merrimack River. This subdistrict includes four MAPC communities, Acton, Bedford, Concord and Littleton, and 13 communities adjacent to the Council District.

These communities would take their supply at the same location as the diversion works proposed for the Ipswich River Subdistrict mentioned above. The two pumping facilities may, in fact, be combined. If, however, both subdistrict systems are developed, it may be necessary to develop either additional storage facilities or a special working schedule to eliminate combined diverting during short periods of extreme low flows and thereby degrading water quality. The need will depend to a large degree on the number of the communities outside the MAPC District which would be supplied by the Concord River Subdistrict system.

3) Charles River Subdistrict: The third subdistrict considered includes the 17 communities in or adjacent to the Charles River watershed and listed below:

Bellingham	Milford	Walpole
Dover	Millis	Wayland
Franklin	Natick	Wellesley
Holliston	Norfolk	Westwood
Medfield	Sherborn	Wrentham
Medway	Sudbury	

Five of these communities can develop potential supplies to adequately meet their projected 1990 demands. The communities in this subdistrict have been subdivided into two groups, the Upper and the Middle Charles River Groups. By developing the abundant potential local supplies of Franklin and Milford and interconnecting the individual systems, the six communities in the Upper Charles River Group can adequately meet their projected 1990 demands. The 11 communities in the Middle Charles River Group can extend the adequacy of their systems by grouping together similar to the Upper Charles River Group.

However, unless the MDC is extended to supply Sudbury, Medfield, Norfolk and Dedham, the combined 1990 demands cannot be met even if all potential supplies are developed. Following the completion of the MAPC study, the NEWS study requested the opinion of the U. S. Geological Survey (USGS) concerning the hydraulic relationship of the well field proposed for the Middle Charles River Group and the River. The USGS replied they felt the proposed well fields were directly linked to the nearby river. With such a link, the well field in essence would be drawing from river flow, particularly in low flow periods. Low flow

conditions in the Charles River at present are a critical factor in the river's water quality. It was felt that any substantial decrease in flow caused by withdrawals for water supply would increase water quality problems. Thus, the NEWS study proposed communities listed as middle Charles to be served by connection to the regional system.

4) Neponset River Subdistrict: Only the town of Sharon in this subdistrict, consisting of Avon, Foxborough, Sharon and Stoughton, can develop supply adequate through 1990. The remaining three subdistrict communities will require an outside supplementing source of supply. The projected 1990 demand of the Neponset River Subdistrict can be adequately met through the development of Ponkapoag Pond as a water supply reservoir. By raising the level of the Pond some 19 feet, adequate storage capacity can be provided to receive flood flows pumped from the Neponset River. Water would be pumped from the Neponset River only during periods when the flow exceeds 25 cubic feet per second (cfs). During dry periods, pumping will be permitted only over a few months of the year. In order to provide sufficient yield, it will be necessary to provide pumping capacity greatly in excess of the estimated safe yield of the system.

5) North River Subdistrict: The fifth subdistrict system investigated would provide supplemental supply to communities located south and southeast of Boston. This North River Subdistrict includes the 15 communities located in the MAPC District, listed below, plus the communities in the Old Colony Planning Council.

Braintree	Holbrook	Randolph
Cohasset	Hull	Rockland
Duxbury	Marshfield	Scituate
Hanover	Norwell	Stoughton
Hingham	Pembroke	Weymouth

Cohasset is the only member community which can develop supplies adequate through 1990. However, providing all of the communities develop their potential supplies, the North River could be developed to supply all of the communities in the subdistrict well beyond the year 1990 with the exception of the towns of Braintree, Weymouth, Randolph and Holbrook. While these communities could be supplied by the North River, it would be more realistic to supplement the supplies of these communities from the MDC, since they are remote from the North River, near the existing MDC system, and their demands would decrease the North River's period of adequacy. The only source that will be

available to supplement the North River once the demands exceed its yield is the MDC, and these four communities would have to be connected to the MDC eventually.

Development of the North River for water supply purposes will require the construction of an on-stream storage reservoir located in the present tidal reach of the North River, a water treatment plant, and pumping and transmission facilities. It is recognized that an impoundment within the tidal reaches of the North River will affect the ecology of the estuary. Early estuarine studies should be made to determine the implications of ecological changes."

6) Summary: Certain groups of communities (particularly those outside Metropolitan Boston) can satisfy their present and projected 1990 needs without relying directly on the MDC. However, they cannot do so unless the MDC supplies certain key communities such as Sudbury, Medfield, Norfolk, Dedham, Braintree, Weymouth, Randolph and Holbrook. It, therefore, becomes apparent that any concept of regional supply for the eastern Massachusetts - Rhode Island Study Area depends on firming up the existing regional system, i.e. the MDC. This is the specific problem addressed by the present survey report.

Also by 1990, many communities not served by the MDC will collectively require water in addition to that available in their immediate watersheds. The development of institutions and physical systems to meet with this regional problem is critical. By 2020, the MDC will also require additional water from a large regional source. These two problems are the subjects of on-going studies.

16. Expected Expansion of the Regional System Service Area

Because potential new water supply sources within the Eastern Massachusetts area are rapidly becoming exhausted, communities are forced to look to regional concepts in water resource development as a means of meeting their future water supply needs. The MDC system represents the largest system in Massachusetts, and for this reason is expected to be called upon to expand its service area considerably by the year 1990.

Under present Massachusetts state Legislation, the MDC system is required to permit any municipality within 10 miles of the State House in Boston to become a member upon application. The MDC is further bound by the same legislation to allow any other municipality within 15 miles of the State House which could be reasonably serviced by the MDC to become, upon application, a member. Any non-member municipality with the approval of the Massachusetts Department of Public Health can be furnished water by the MDC.

In an attempt to determine what communities might be serviced by the regional system in 1990, four groups of municipalities were identified. These are listed below and shown on Plate No. 5.

1) Cities and towns presently serviced by the MDC.

2) Municipalities who cannot meet their future demands from local sources and who have no other reported feasible alternative but to join the MDC system.

3) Communities with a number of reported feasible alternatives including joining the MDC system.

4) Those cities and towns who can meet their future demands from local sources or from other regional systems not including the MDC system.

The MDC system presently is made up of 32 member communities, 25 of which are wholly served. The MDC also supplies water to 10 non-member communities which draw from either the Chicopee Aqueduct in the Springfield area or from the Wachusett-Sudbury reservoir system. These cities and towns, listed in Table 9, obtain water from the MDC because there simply are no other feasible sources of water supply available to them. Therefore, with the exception of Peabody, it has been assumed that all additional future water demands originating from

these communities will be met completely by the MDC system. Peabody's additional demand may be met by further development of the Ipswich River.

The remaining communities in the study area were then investigated to determine if they can meet their 1990 water demand locally and then, if not, whether it is feasible for them to join the MDC system. The communities listed in Table 10 have no other reported feasible alternative to meet their additional future water demands other than joining the MDC system. Because they all can be reasonably served by the MDC, these cities and towns are included in the potential 1990 service area.

The third category of communities are listed in Table 11. These cities and towns have a number of feasible alternatives including connection to the MDC system. Other alternatives available to the municipalities include development of the Merrimack, Ipswich and North Rivers as well as ground water resources in some cases.

Those communities not anticipated to join the MDC system by 1990 are shown on Plate No. 5. Based on a review of these municipalities' 1990 water supply needs, it appears adequate local resource is available or entrance to another regional system is a more feasible solution.

The 1990 water demands on the Quabbin - Wachusett Reservoirs (MDC system) were then estimated for the three groups of communities which may be serviced. Supply demand estimates, as described in Appendix B, were derived using both population and industrial output forecasts. Population increases were combined with estimates of future per capita usage to provide supply needs domestic, commercial and public usage. Industrial output forecasts using a water use per dollar output analysis allowed the estimation of supply needs for heavy water using industry. Both estimates were then combined to give total future water requirements.

Once the supply requirements were established, the additional development necessary to meet these needs was determined. This was accomplished by subtracting safe yields of existing and anticipated supply sources from the total estimated needs. Using this methodology, the existing MDC's service area 1990 water demand was estimated to be about 410 million gallons per day (mgd). If the cities and towns with no other reported alternative were to join the MDC, total demand for 1990 was estimated to be about 441 mgd. If all communities noted as including the MDC as an alternative source were serviced, then 519 mgd would be needed in 1990.

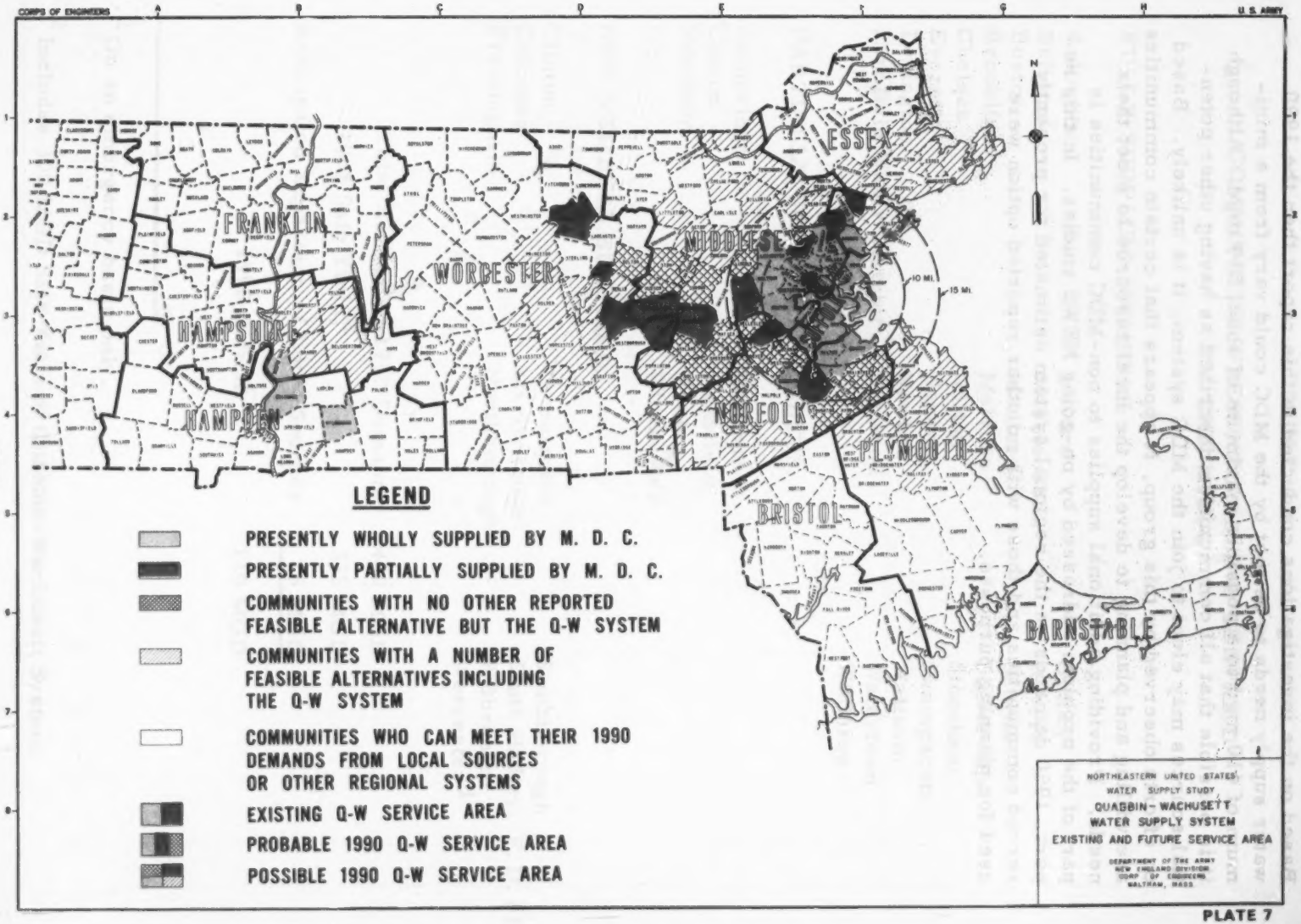

CORPS OF ENGINEERS
U.S. ARMY
ESSEX
FRANKLIN
WORCESTER
MIDDLESEX
10 MI.
15 MI.
HAMPSHIRE
HAMPDEN
NORFOLK
PLYMOUTH
BRISTOL
BARNSTABLE
N
LEGEND
PRESENTLY WHOLLY SUPPLIED BY M. D. C.
PRESENTLY PARTIALLY SUPPLIED BY M. D. C.
COMMUNITIES WITH NO OTHER REPORTED FEASIBLE ALTERNATIVE BUT THE Q-W SYSTEM
COMMUNITIES WITH A NUMBER OF FEASIBLE ALTERNATIVES INCLUDING THE Q-W SYSTEM
COMMUNITIES WHO CAN MEET THEIR 1990 DEMANDS FROM LOCAL SOURCES OR OTHER REGIONAL SYSTEMS
EXISTING Q-W SERVICE AREA
PROBABLE 1990 Q-W SERVICE AREA
POSSIBLE 1990 Q-W SERVICE AREA
NORTHEASTERN UNITED STATES WATER SUPPLY STUDY
QUABBIN - WACHUSETT WATER SUPPLY SYSTEM
EXISTING AND FUTURE SERVICE AREA
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 7

Based on the investigations conducted in this report then the 1990 water supply needs to be met by the MDC could vary from a minimum of 410 mgd to a possible maximum of about 519 mgd. Although it is possible that all communities described as having other potential sources may elect to join the MDC system, it is unlikely. Based on efforts observed by this group, it appears that certain communities are willing and planning to develop the local resource to meet their needs. Providing additional supplies to non-MDC communities is part of the problem addressed by on-going NEWS studies. In this report, 1990 demands on the regional system estimated for presently served communities and those with no other reported option were used for planning purposes.

TABLE 9

COMMUNITIES PRESENTLY BEING SERVICED BY THE M.D.C.

FULLY SUPPLIED MEMBERS:

Arlington	Malden	Quincy
Belmont	Marblehead	Revere
Boston	Medford	Saugus
Brookline	Melrose	Somerville
Chelsea	Milton	Stoneham
Everett	Nahant	Swampscott
Lexington	Newton	Waltham
Lynnfield Water District	Norwood	Watertown
		Winthrop

PARTIALLY SUPPLIED MEMBERS:

Cambridge	Peabody
Canton	Wakefield
Needham	Weston
	Winchester

NON-MEMBERS SUPPLIED:

Clinton	Leominster	Southborough
Chicopee	Marlborough	South Hadley, F.D. #1
Framingham	Northborough	Wilbraham
		Worcester [1]

Total Estimated 1990 Demand	450 MGD
1965 Safe Yield [2]	335 MGD
Anticipated Expansion of Local Sources	5 MGD
1990 Deficit	110 MGD

[1] On an emergency basis only.

[2] Includes 300 MGD Safe Yield of Quabbin-Wachusett System.

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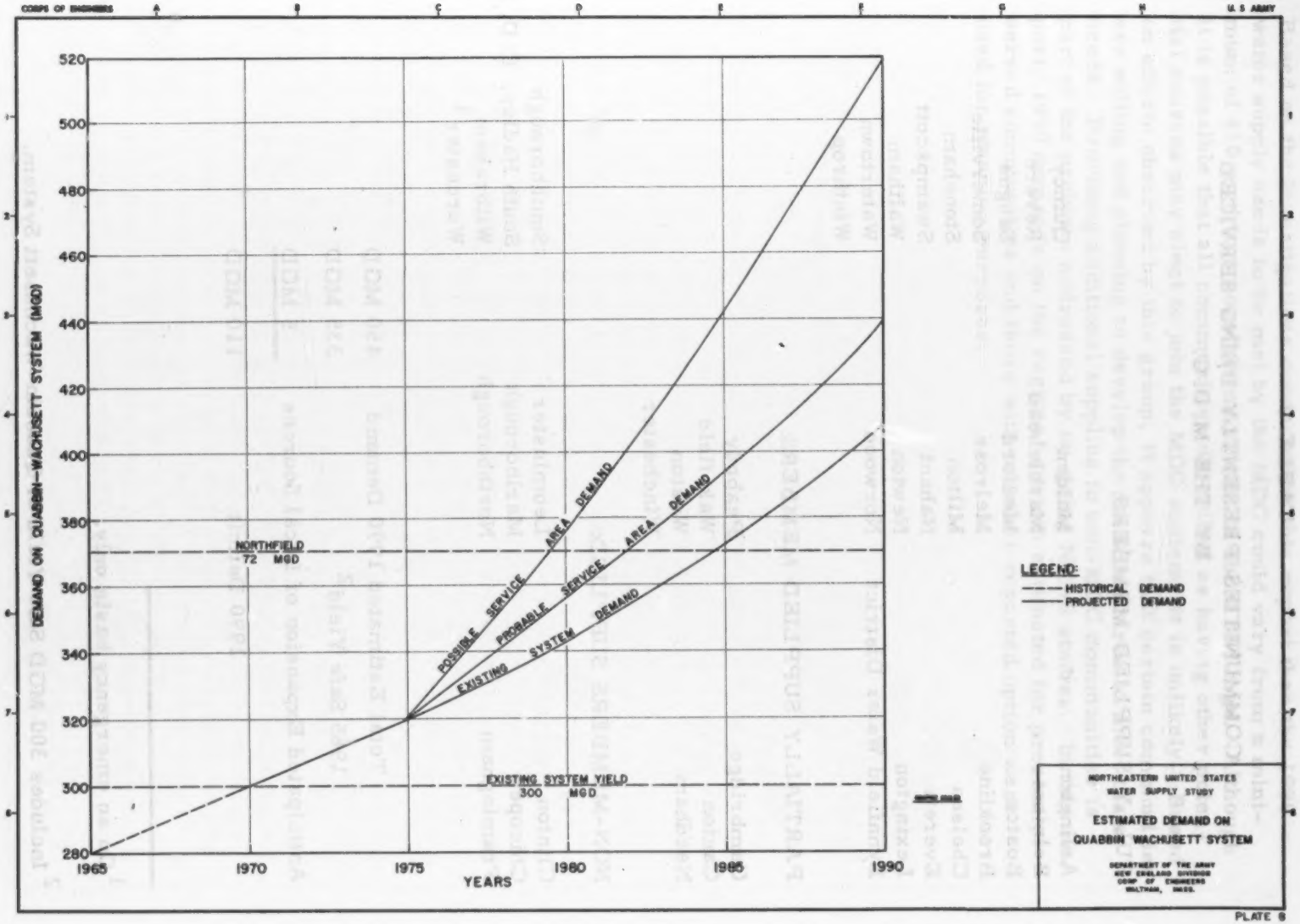
CORPS OF ENGINEERS
U.S. ARMY
DEMAND ON QUABBIN-WACHUSETT SYSTEM (MGD)
520
500
480
460
440
420
400
380
360
340
320
300
280
1965
1970
1975
1980
1985
1990
YEARS
NORTHFIELD
72 MGD
EXISTING SYSTEM YIELD
300 MGD
POSSIBLE SERVICE AREA DEMAND
PROBABLE SERVICE AREA DEMAND
EXISTING SYSTEM DEMAND
LEGEND:
HISTORICAL DEMAND
PROJECTED DEMAND
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
ESTIMATED DEMAND ON
QUABBIN WACHUSETT SYSTEM
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 8

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TABLE 10

COMMUNITIES WITH NO OTHER REPORTED OPTION

Ashland	Millis
Avon	Natick
Bolton	Norfolk
Braintree	Randolph
Dedham	Sherborn
Dover	Stoughton
Holbrook	Stow
Holliston	Sudbury
Hudson	Wellesley
Lincoln	Westwood
Maynard	Weymouth
Medfield	Woburn

Total Estimated 1990 Demand	74 MGD
1965 Safe Yield	39 MGD
Potential Local Sources	4 MGD
1990 Deficit	31 MGD

TABLE 11

COMMUNITIES WITH OTHER OPTIONS INCLUDING THE M.D.C. SYSTEM

IPSWICH RIVER:

Beverly	Ipswich	Peabody
Danvers	Lynn	Reading
Essex	Lynnfield	Rockport
Gloucester	Middleton	Salem
Hamilton	North Reading	Topsfield
		Wilmington

Estimated 1990 Demand	58 MGD
1965 Safe Yield	47 MGD
1990 Deficit	11 MGD

CONCORD RIVER:

Acton	Concord
Bedford	Littleton

Estimated 1990 Demand	12 MGD
1965 Safe Yield	5 MGD
1990 Deficit	7 MGD

MERRIMACK RIVER:

Billerica	Dracut
Chelmsford	Tewksbury
	Tyngsborough

Estimated 1990 Demand	22 MGD
1965 Safe Yield	12 MGD
1990 Deficit	10 MGD

TABLE 11 (cont'd)

NORTH RIVER:

Abington	Hanson	Pembroke
Brockton	Hingham	Rockland
Duxbury	Hull	Scituate
Halifax	Marshfield	Whitman
Hanover	Norwell	

Estimated 1990 Demand	39 MGD
1965 Safe Yield	28 MGD
1990 Deficit	11 MGD

CHARLES RIVER:

Bellingham	Medway
Foxborough	Wrentham

Estimated 1990 Demand	9 MGD
1965 Safe Yield	5 MGD
1990 Deficit	4 MGD

MILL RIVER:

Hopedale	Mendon
Hopkington	Milford

Estimated 1990 Demand	6 MGD
1965 Safe Yield	2 MGD
1990 Deficit	4 MGD

TABLE 11 (cont'd)

WORCESTER AREA:

Auburn	Holden	Princeton
Berlin	Leicester	Shrewsbury
Boylston	Millbury	West Boylston
Grafton	Paxton	Worcester

Estimated 1990 Demand	47 MGD
1965 Safe Yield	26 MGD
1990 Deficit	21 MGD

COLLEGE AREA:

Amherst	Hadley
Belchertown	Pelham
Granby	South Hadley, F. D. #2

Estimated 1990 Demand	10 MGD
1965 Safe Yield	4 MGD
1990 Deficit	6 MGD

WEST SPRINGFIELD:

Estimated 1990 Demand	7 MGD
1965 Safe Yield	3 MGD
1990 Deficit	4 MGD

TOTAL ESTIMATED 1990 DEMAND	210 MGD
TOTAL 1965 SAFE YIELD	132 MGD
TOTAL 1990 DEFICIT [1]	78 MGD

[1] Deficit shown is expected to be met by local resource development.

17. Capability of System to Meet Future Needs

A. Source

The estimated yield from the existing MDC sources of supply is about 300 mgd. In 1971, the average daily demand of all communities serviced by the system was about 322 mgd. At present then, withdrawals from the system exceed the available dependable yield. The most striking example of this demand in excess of supply situation is at Quabbin Reservoir, the main storage facility of the system. From a low pool elevation of 495 feet (full pool 530 feet) the reservoir has been unable to replenish its storage.

Forecast demands on the system for 1990 indicate an additional increment of 141 mgd of yield will be necessary unless water use practices of the serviced population are altered dramatically.

The MDC as a result of their analysis have reported to the Massachusetts State Legislature the next step in providing the supply necessary to meet future needs is the diversion via the Northfield Mountain [1] Project. At a NEWS meeting held in Boston, Massachusetts, in May 1970, local, State and Federal officials agreed that the Northfield Mountain Project was a viable element in any regional water supply plan.

If the yield from Northfield Mountain is made available, the total dependable yield available to the system would be about 372 mgd. Based on the forecast demands, this project would meet supply needs to about 1984. In order to meet the short-range 1990 needs then an additional source of supply will be needed.

In this report, the potential of diverting water from the Millers River Basin, a tributary of the Connecticut, is being investigated. Depending on the method of development employed, this source could produce 76 mgd of additional supply.

Development of the Northfield Mountain Project as described in this report then could add about 25 percent to the existing system yield. This addition, when combined with the Millers River Basin yield, would allow adequate supplies within the serviced communities to about 1990.

B. Transmission Facilities

Although the intent of this Interim Report of Survey was to investigate new sources of supply to meet future needs, a preliminary analysis of the MDC's transmission facility was also conducted. The purpose of

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[1] Subject of a companion NEWS report.

evaluating the transmission facilities was not to include any needed improvements as recommendations for authorization, but rather to present a full picture of the system's present capability.

In order to determine the adequacy of the major transmission aqueducts, the peak demands for the system had to be estimated. Variations in water demands due to seasonal weather changes have always been important considerations in the design of water supply systems in the northeastern United States and particularly in New England. Historically, summer periods have promoted exceptionally high water demands which quite often last for several weeks. In most cases, these peak demands must be met by the water supply storage reservoirs, since storage within the distribution system itself cannot usually be economically constructed to handle these peak loads.

The ratio of the maximum day demand to the average daily demand is directly related to the type and character of the development within the community or communities to be served. The present MDC system, as described earlier, services 32 member communities within the greater Boston area. Twenty-five of the communities depend wholly upon the system to supply their water needs, while the remaining seven communities make maximum use of their own sources and only rely upon the MDC system to supply their peak demands. The 25 wholly supplied communities range from completely residential in character to the inner core cities with industrial and commercial development. During the recent drought of the 60's, the ratio of the maximum day demand to the average daily demand for the city of Boston reached a high of 1.24, while the ratio for the total 25 communities reached 1.65. This difference has been attributed to the effect of the suburban communities peak demands upon the system. If the MDC is called on to expand its service area, it will be adding suburban communities which are largely residential in nature. Thus, the maximum daily demand ratio can be expected to increase above the present high figure of 1.65. The amount of increase will, of course, depend on what portion of the total water demand upon the system the new members demand represents.

To determine what increase, if any, the transmission facilities would have to supply by 1990, peak demand characteristics of a number of eastern Massachusetts communities were examined. Based on this investigation, it appeared a maximum day ratio of 1.70 to average daily demand represented a reasonable value for planning purposes. A comparison of this figure to other historic and projected maximum day data for large metropolitan systems in the Northeastern United States was then made and proved to be comparable.

Applying the maximum day ratio to demands forecast in the Boston Metropolitan area, it appears the present transmission facilities from Wachusett Reservoir to the Boston City tunnel system may be inadequate. This inadequacy can be primarily attributed to the limiting carrying capacity of the Hultman Aqueduct.

At present, the Metropolitan District Commission has under way a large scale (one million dollar) investigation of its water supply system. Included in this investigation will be an examination of the future courses of action which the MDC may pursue with regard to supply, demand and conveyance facilities. One of the major study elements will be the adequacy of the system's aqueducts. The results of this investigation will describe problem areas and corrective actions needed.

SECTION VII

DESCRIPTION OF THE PROJECT

19. General

Early in 1966, the Western Massachusetts Electric Company, the Connecticut Light and Power Company and the Hartford Electric Light Company filed an application for permission to build a pumped storage hydroelectric facility atop Northfield Mountain in Franklin County, Massachusetts. Permission to build the facility was given and construction commenced in 1966 and is scheduled for completion in 1973. When completed, the Northfield Mountain Project will have a generating capacity of one million kilowatts and will cost an estimated $140 million.

In the initial application made by the power companies to the Federal Power Commission, the potential of adding a municipal water supply function to the facility was recognized. This multiple use would be achieved by utilizing the pumping and storage facilities to supply Connecticut River water during periods of high flow to Quabbin Reservoir. Water from Quabbin would then be supplied to serviced municipalities, both within the Connecticut River Basin and to out-of-basin communities in the Boston Metropolitan area.

Following the power companies' proposal to use power facilities as a diversion device, the Metropolitan District Commission filed legislation with the Massachusetts State Legislature regarding use of Northfield Mountain for a dual water supply use. This legislation was adopted by the Commonwealth of Massachusetts in Chapter 669 of the Acts, 1967, and provided $25 million in funds for the necessary water supply diversion facilities.

In 1969, the MDC filed additional legislation with respect to the Northfield Mountain Proposal. This legislation requested an additional $20 million for the diversion facilities' construction, changed the control flow upon which the diversion would be based to a more favorable gaging location downstream and allowed an opportunity for the MDC to explore other potential diversion locations besides Northfield. When

this additional legislation was presented to the Massachusetts Legislature, a considerable amount of local Connecticut River Basin opposition was voiced on the bill. In response to this protest, the Legislature ordered a special study commission to study the issues raised by the dissenting voices and report their findings on the diversion.

The findings of this special study commission were reported to the Massachusetts Legislature in May 1970. In brief, the special study commission approved the diversion plan, although a further supplementary report by three of the legislative members of the Commission raised the question of radioactive pollution from a nuclear power plant being constructed in Vernon, Vermont, about ten miles upstream from the Northfield Mountain intake. The Massachusetts Advisory Commission on Radiation presented its findings on the radioactive danger to the joint Massachusetts Senate - House Committee on Urban Affairs. These findings conclude that even with the Vermont plant in operation, the Metropolitan Water System will not be harmed by diverting Connecticut River water.

The Special Study Commission submitted proposed legislation containing provisions reflecting the above and other conclusions. Prior discussions between the MDC and the electric utilities had produced a preliminary draft of an agreement containing provisions not usually included in agreements to which the Commonwealth of Massachusetts is a party. These provisions included payments to reimburse the utility for costs of constructing the diversion structures needed to store and divert the water from their installation, reimbursement for their expenses in insurance and local taxes, and provisions for the referral of disagreements to arbitration procedures. The Special Study Commission included provisions in its proposed legislation to provide for these aforesaid matters. However, this legislation was not enacted by the Massachusetts Legislature. In the legislation which was enacted as Chapter 766 of the Acts of 1970, however, provisions expressly limiting the quantity and location of the diversion were included. In view of this, the MDC is currently preparing a new draft of an agreement designed to arrive at a mutually satisfactory arrangement with the utility companies.

To date no agreement has been reached on this element of the project. Discussions held with officials of the MDC, however, indicate an agreement can be reached on this present impasse.

20. Facilities Required and Project Operation

A. Hydroelectric Facilities and Operation

The Northfield Mountain hydroelectric project has been constructed in Northfield and Erving, Massachusetts. The location of the project, shown on Plate No. 9, is about 9 miles downstream from the New Hampshire - Vermont - Massachusetts state boundaries, about 49 miles and 75 miles upstream from Springfield, Massachusetts, and Hartford, Connecticut, respectively.

The pumped storage project consists of a high level storage reservoir on Northfield Mountain, underground pump-turbine facilities and low level storage in the Turners Falls pool. The high level reservoir consists of a system of dams and spillways arranged to provide a 17,000 acre-foot storage about 800 feet above the Turners Falls pool. The pump - turbine facilities, consisting of 4 - 250,000 KW units, are connected to the upper reservoir by a 31 foot diameter, concrete lined penstock excavated in the rock. A 40 foot high and 26 foot wide horseshoe tunnel connects the pump-turbines to the Turners Falls pool. A plan of the facilities is shown on Plate No. 10.

New storage in the Turners Falls pool would be provided by raising the dam to elevation 185.0 mean sea level. The Montague section would have bascule gates and the Gill section would have hinged flash boards. The two sections would be connected by a new dam on the island consisting partially of bascule gates and partially flash boards.

The Northfield Mountain project will be operated principally for power purposes. When low cost, base load power is available, water would be pumped and when high value, peaking power is needed, electric energy would be generated. Base load power is usually available nights and weekends. Peaking power is usually needed on weekdays for periods in the morning, afternoon and early evening. Present planning would pump the Upper Reservoir full each weekend, generate each day and partially refill each night.

1) Northfield Mountain Power House - The four 250,000 KW units, each capable of pumping 3,000 cfs (average 2,500 cfs) would be operated individually either to supply the needed power or to utilize the low cost energy available. The total maximum generation discharge would be 18,000 cfs when all units were operating. The total maximum pumping with all units running would be 12,000 cfs (average 10,000 cfs). The power company's proposed pumping operation would utilize storage in Turners Falls pool and be independent of Connecticut River flow.

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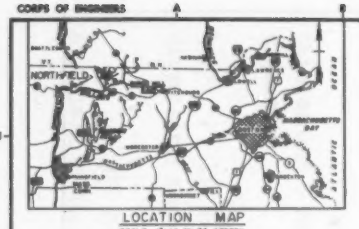
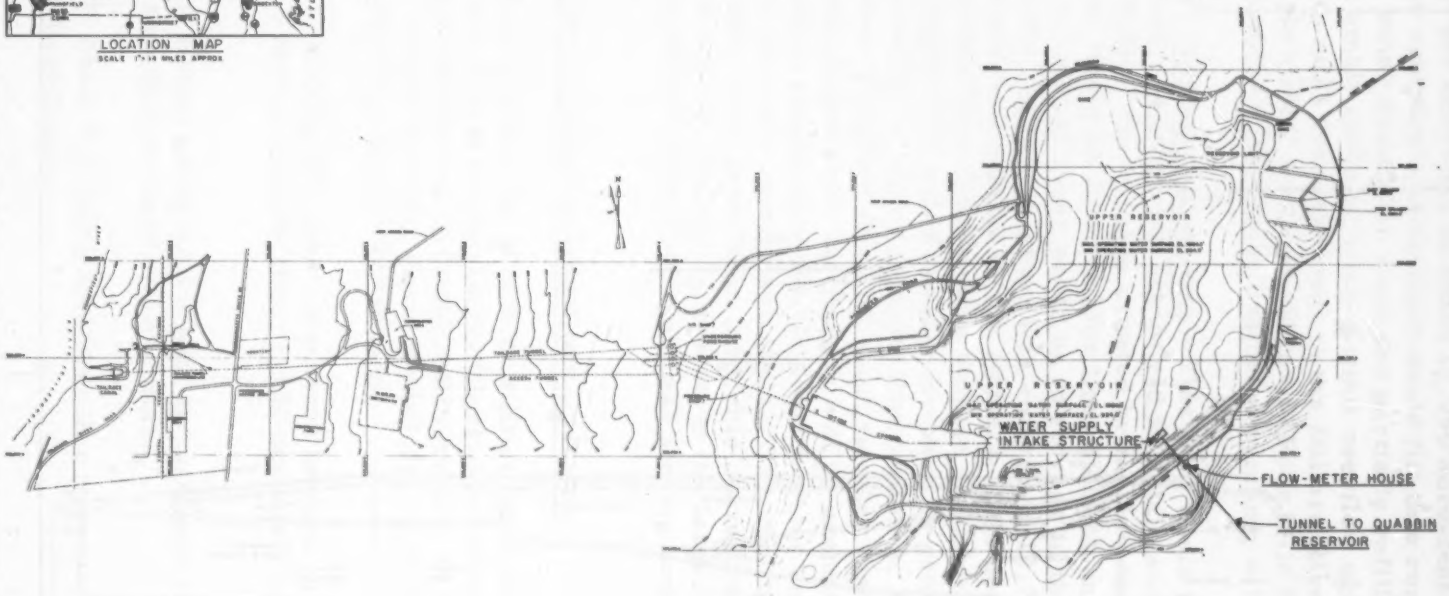


LOCATION MAP

SCALE 1" = 10 MILES APPROX



GRAPHIC SCALE

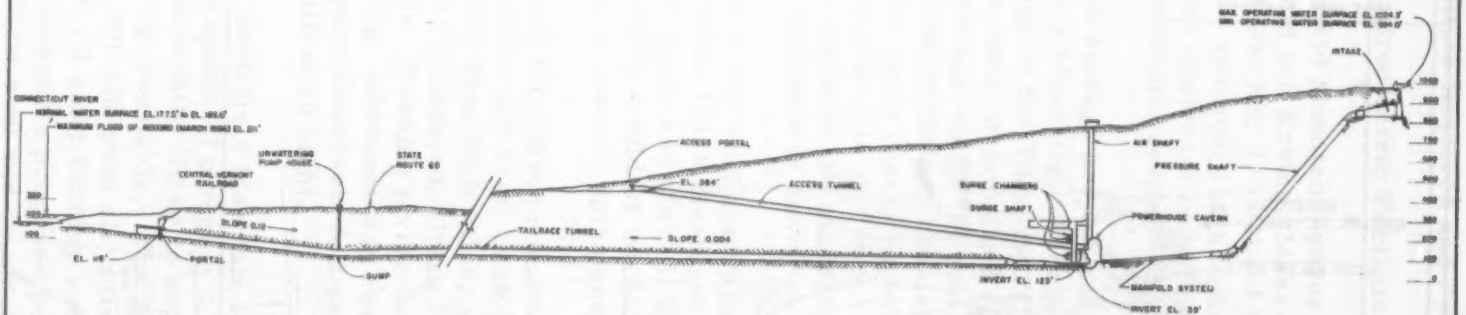
1" = 400'

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

NORTHFIELD MOUNTAIN
PUMPED STORAGE PROJECT

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 9



SECTION

SCALE – FEET

1" = 200'

NOTE: ELEVATIONS REFER TO USGS MEAN SEA LEVEL DATUM

NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

SECTION THROUGH POWER HOUSE AND WATER CONDUITS
NORTHFIELD MT. PUMPED STORAGE PROJECT

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 10

2) Upper Reservoir - The total capacity of the upper reservoir is 17,000 acre-feet of which 12,750 acre-feet would be usable. The power company's operations would fill this reservoir each weekend, use water during the week and partially refill each night. For safety, a small spillway would permit overflow of local inflow (about 1/2 square mile drainage area) to the Millers River. A larger spillway at higher level would discharge to Four Mile Brook in the event of an operational failure which continued pumping with a full reservoir.

3) Turners Falls Pool - This pool would perform two separate functions, storage for Northfield Mountain and pondage for Turners Falls. The storage created by the new bascule gates and flashboards would be reserved for Northfield Mountain. Thus, 12,750 acre-feet of water would be in storage in the Turners Falls pool when the Upper Reservoir was empty and 12,750 acre-feet of storage would be available in the Turners Falls pool when the Upper Reservoir was full. To maintain storage available in Turners Falls pool, the Applicants would operate the bascule gates during generation and pumping in such a manner that outflow at Turners Falls equals reservoir inflow from all sources other than Northfield Mountain and that downstream discharges will be unchanged. The bascule gates would be raised to retain generation water and lowered during pumping to maintain storage available. The only change expected from Turners Falls generation from this operation will be a slight increase in electric energy by reason of the larger head available at times when the Turners Falls pool was storing water for Northfield Mountain.

B. Water Supply Facilities and Operation

As described earlier, the electric utilities have made an offer to the Metropolitan District Commission (Boston) to include provisions for water supply diversions to Quabbin Reservoir. In order to include this water supply function, three modifications to the pumped storage facilities are necessary. These are:

1) Raising the upper reservoir located on Northfield Mountain about 4 feet to provide about 1,150 acre-feet of additional storage capacity.

2) Provision of head works at the upper reservoir for the diversion aqueduct to Quabbin Reservoir.

3) About 9.8 miles of connecting aqueduct and outlet facilities at Quabbin Reservoir.

The first two items necessary for diversion have been essentially completely constructed at the upper reservoir on Northfield Mountain by the electric utility construction forces. A plan of these facilities is shown on Plate No. 9.

The third item necessary for water supply diversion is presently in preliminary design stages by engineers at the MDC. At present, plans indicate water would be diverted from the upper reservoir through an eight foot diameter steel pipe constructed in the east dike of the Northfield Mountain upper reservoir. Water would be withdrawn at an average rate of 375 million gallons per day and delivered to an intake shaft of the Northfield - Quabbin tunnel aqueduct. A plan of the aqueduct alignment is shown on Plate No. 11.

The intake down shaft would be a scroll type configuration with a diameter of 16 to 18 feet. Water would be conveyed from a maximum upper reservoir pool elevation of 1004 feet msl in this vertical shaft to the aqueduct at elevation 300 feet msl.

The aqueduct would be a 10 foot finished diameter tunnel with a reinforced concrete liner. From the downtake shaft, the aqueduct would run about .53 miles to the vicinity of the south bank of the Millers River. At the Millers, a 10 foot diameter construction shaft would be excavated.

Continuing to Quabbin, the aqueduct would be driven about 3.0 miles to the vicinity of Bullard Hill. In this tunnel reach, the aqueduct would rise from the 300' elevation at the Millers River to elevation 440'. A second construction shaft would be provided at this location as shown on Plate No. 11.

From Shaft No. 3, the tunnel would continue about 6.2 miles to the uptake shaft located in Rattlesnake Hill adjacent to Quabbin Reservoir. At Rattlesnake Hill, an uptake shaft would be driven from elevation 440 to elevation 500. At elevation 500, the tunnel would be enlarged from ten to 30 feet in width in a 150 foot long transition zone. Flow entering Quabbin from the transition zone would be conveyed in a 30 foot wide channel cut to the main channel of the Middle Branch of the Swift River.

In operating the project for water supply purposes, the electric utilities would extend their pumping operation about 1-1/2 hours per day to pump about 1,150 acre-feet (375 mg) of water to the upper reservoir each day when Connecticut River flow is in excess of 17,000 cfs at Montague City USGS gaging station. On a long term average, flow at Montague

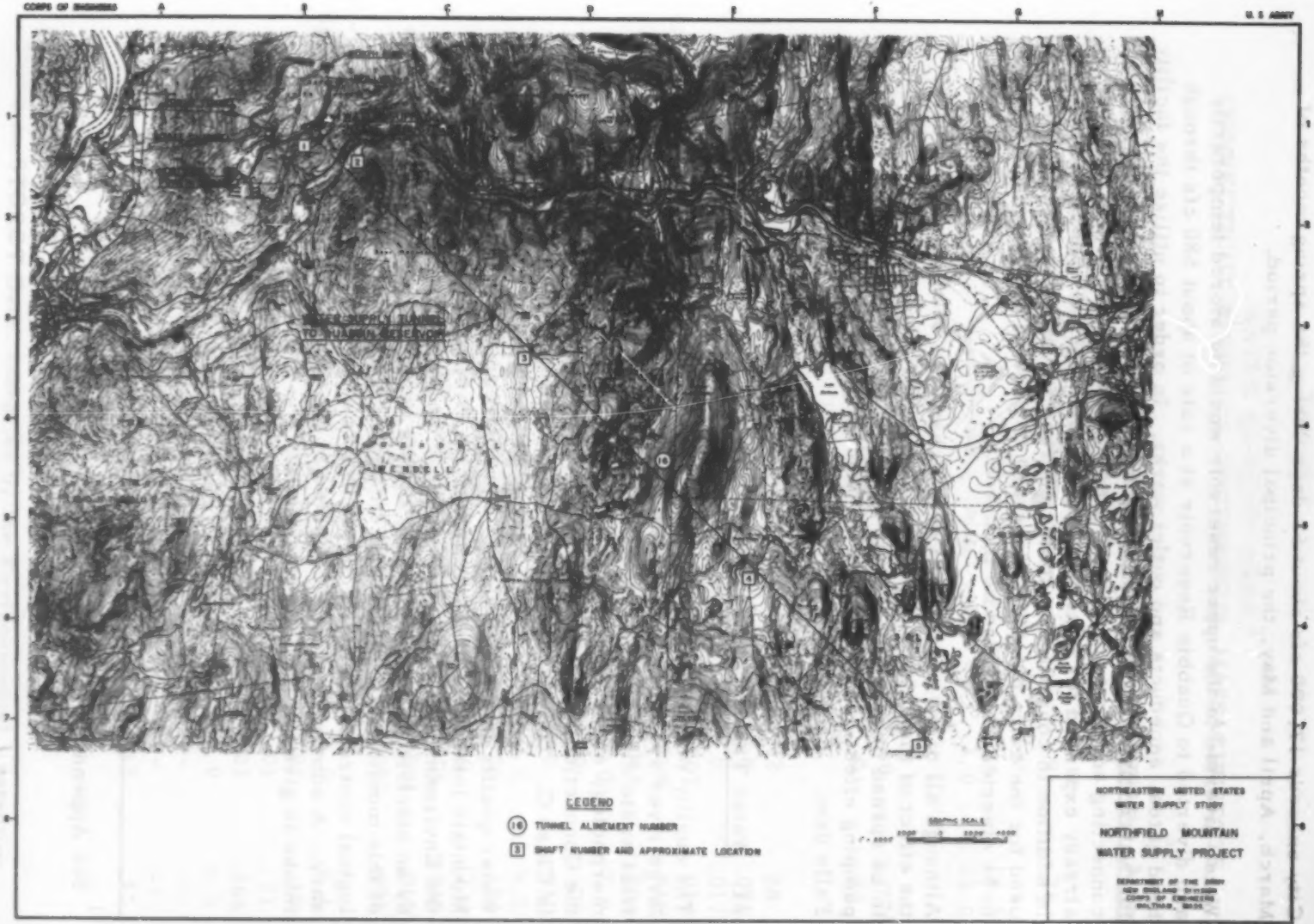

CORPS OF ENGINEERS
U.S. ARMY
WATER SUPPLY TUNNEL TO QUABBIN RESERVOIR
ERVING
WENDELL
LEGEND
(10) TUNNEL ALINEMENT NUMBER
[3] SHAFT NUMBER AND APPROXIMATE LOCATION
SCALE
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
NORTHFIELD MOUNTAIN
WATER SUPPLY PROJECT
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 11

City exceeds 17,000 cfs about 58 days during the spring months of March, April and May, the principal diversion period.

Water diverted to the upper reservoir would be stored temporarily and diverted to Quabbin Reservoir at a rate of about 580 cfs through head gates, aqueducts and outlet works. In order to utilize the facility for water supply, the operating agency must design and construct the connecting aqueduct and pay the electric utilities for the $2 million already expended for construction completed at the upper reservoir. In addition to construction costs, charges for off peak electric energy used for the extra pumping necessary to provide the volume of water to be diverted would also be incurred.

Although all of the operational details have not been planned to date, the effect of the extra pumping necessary for water supply is expected to be spread over a full 24 hour period. This spreading of the extra pumping effect can be attained by bascule gate operation at the Turners Falls dam.

21. Water Treatment Required

The quality of the Connecticut River, as is the usual case of most large river systems, varies with the upstream municipal and industrial waste discharges, river flow, velocity, time of year and geomorphology of the region. At present, the general classification of the Connecticut River in the vicinity of this project's diversion intake is Class C. The adopted future classification of the river reach is B.

Water quality in the vicinity of, and upstream from, the Northfield Mountain intake has been sampled for a varying number of years by the Environmental Protection Agency, by State Health Departments, by an electric utility and as part of this report under contract. [1] Results of this monitoring indicate that treatment for bacteriological and biological control prior to its direct use as a water supply would be necessary. A summary of data collected in the vicinity of the pumped storage intake is given in the following table:

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[1] See Appendix D and Appendix G.

TABLE 5

WATER QUALITY DATA [1]
CONNECTICUT RIVER AT NORTHFIELD, MASSACHUSETTS

	Unit	Maximum	Minimum	Mean
Physical				
Color	Units	60	9	26
Odor	--	--	--	--
Temperature	°C	32.5	--	16.5
Turbidity	Jackson Units	143	1.0	23.0
Microbiological				
Coliform Organisms	MF/100 ml	60,000	40	5,775
Fecal Coliforms	MF/100 ml	380	0	89
Inorganic Chemicals				
Alkalinity	mg/l	54	12	28
Ammonia	mg/l	1.1	0	.096
Arsenic	mg/l	.06	0	.017
Barium	mg/l	.02	.007	.014
Boron	mg/l	.029	.004	.016
Cadmium	mg/l	.02	.001	.004
Chloride	mg/l	45	3.0	7.9
Chromium, hexavelent	mg/l	.006	0	.002
Copper	mg/l	.024	0	.010
Dissolved Oxygen	mg/l	14.8	2.2	9.2
Fluoride	mg/l	.31	.05	.126
Hardness	mg/l	58	20	37.4
Iron	mg/l	.079	.005	.035
Lead	mg/l	.003	.0002	.015
Manganese	mg/l	.009	.0003	.005
Nitrates plus Nitrites	mg/l			
pH	--	8.6	2.0	7.1
Phosphorus	mg/l	1.0	.01	.10
Selenium	ug/l	.01	.01	.01
Silver	ug/l	.40	.07	.264
Sulfate	mg/l	22	3.0	9.3
Total Dissolved Solids	--	--	--	--
Uranyl Ion	--	--	--	--
Zinc	mg/l	.7	.12	.17

[1] Based on STORET Data, compiled by the Environmental Protection Agency.

TABLE 5 (cont'd)

	Unit	Maximum	Minimum	Mean
Organic Chemicals				
Carbon chloroform extract	ug/l	159.0	39.0	89.3
Cyanide	mg/l	.02	0	.01
MBAS	mg/l	.09	.02	.05
Oil and Grease	--	--	--	--
Pesticides				
Aldrin	ug/l	.00	.00	.00
Chlorodane	ug/l	.00	.00	.00
DDT	ug/l	.01	.00	.0009
Dieldrin	ug/l	.022	.000	.007
Endrin	ug/l	.025	.000	.0035
Heptachlor	ug/l	.00	.00	.00
Heptachlor Epoxide	ug/l	.001	.000	.0001
Herbicides	ug/l	.00	.00	.00
2,4-D plus 2, 4, 5-T plus 2, 4, 5-TP				
Radioactivity				
Radium - 226	pc/l	--	--	--
Strontium - 90	pc/l	3.1	.3	1.23

If water drawn from the Connecticut River were to be used to directly feed water supply distribution systems, then at least complete conventional treatment would be required. In the Northfield Mountain diversion, however, water withdrawn from the river would be conveyed to storage at Quabbin Reservoir. Storage time[1] within Quabbin could provide an opportunity for natural purification processes, thus precluding extensive treatment prior to the introduction of the river water to Quabbin.

There are a number of questions on the "treatment plant" capacity which Quabbin possesses. To date, the reservoir has not had large demands placed upon it. The present feeder streams, the Swift and Ware Rivers, are free of high oxygen demanding materials, industrial and municipal pollution, and other sources of pollution. Therefore, the streams that feed Quabbin are low in coliforms, oxygen demand, turbidity and all the other water quality parameters which are used in judging the suitability of a water supply.

The continuing high quality of the reservoir's drainage basin streams and the resulting supply are a testimony to the Metropolitan District Commission's watershed management program. Thus with the exception of color, little is required of Quabbin's treatment plant capacity.

The addition of Connecticut River water to Quabbin presents a different situation for the reservoir. Quality of Connecticut River water, due to both man-made influences, such as waste discharge and natural phenomena, such as bank erosion, is inconsistent then with the present reservoir feeder streams. It can be expected, therefore, that Quabbin's "treatment plant" capability will be tested with the addition of the Connecticut River water.

At present, no one knows with certainty exactly what the reservoir's "treatment plant" capacity is. Preceding the actual diversion, additional studies, conducted by both the Metropolitan District Commission and the Environmental Protection Agency, are planned. Included in these planned studies will be observation of water quality parameters within the upper reservoir of Northfield Mountain and bench scale models of Quabbin Reservoir water mixed with Connecticut River water. The results of these investigations should add more hard data on the potential response of Quabbin to diverted waters.

All investigators agree that any deleterious impact, if any, on Quabbin water quality would develop slowly, thus allowing a period of observation and monitoring in the prototype reservoir itself. Since maximum

[1] See Appendix D for results of hydrodynamic studies of Quabbin Reservoir.

dilution of the lower quality river water with reservoir water may be desirable, the option of including a dual outlet system to different legs of the reservoir has been considered. Under this plan, water would be conveyed from Northfield Mountain to Quabbin. Depending upon characteristics of the receiving water body, such as pool elevation quality, etc., the diverted flow could be split between the Middle Branch or West Branch of the reservoir. To provide for this future flexibility, if needed, the Northfield - Quabbin Aqueduct would include a tunnel stub heading toward the West Branch of the reservoir. If, in the future after diversion, the water quality monitoring program indicated a deterioration of water quality, a tunnel leg could be constructed to the West Branch of Quabbin Reservoir, thus insuring maximum dilution and flexibility in diversion operations.

In summary, then, water quality data analyzed in this report indicates no water treatment would be necessary prior to the diversion of Connecticut River water to Quabbin. This conclusion is based on the recognition that within Quabbin Reservoir a capability for natural purification processes exist. An exact quantification of this capability, however, is not possible. To insure, then, that these capabilities are not overtaxed, a series of investigations prior to the diversion coupled with observation and monitoring after diversion is necessary.

22. Waste Treatment Required

As described in the previous section, water quality data collected from the Connecticut River indicates the river can be used as a supply source after reservoir storage detention and adequate measures for disinfection. The river itself, however, is subject to waste loads from both municipal and industrial waste discharges, many of which are presently untreated. The high dilution flows during diversion periods considered in this study act to reduce the concentrations of these pollutants. If pollution loads increase unchecked in the future, however, there is no assurance that this dilution effect of the river will be sufficient to produce an adequate quality water at the intake.

Recent reports by the Environmental Protection Agency,[1] as well as studies conducted as part of this investigation, have documented the location and amounts of waste discharges entering the Connecticut River above the Northfield intake.

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[1] Comprehensive Water and Related Land Resources, Connecticut River Basin, Appendix D, Water Supply and Water Quality.

From the Connecticut River headwaters to the introduction of the Upper Ammonoosuc River in Northumberland, New Hampshire, the river is free of major sources of organic pollution. Above this confluence, only a few smaller communities contribute untreated municipal waste. From the Upper Ammonoosuc to the intake, however, large amounts of industrial and municipal wastes are discharged to the river. The following table illustrates the total waste measured in BOD_5 to the river in 1960 from both industrial and municipal sources upstream of the proposed diversion intake.

TABLE 6

WASTE LOADS[1] TO CONNECTICUT RIVER BASIN STREAMS

1960

Pounds Per Day BOD_5

Stream	Municipal	Industrial
Upper Ammonoosuc	255	154,000
Israel	250	--
Johns	230	--
Ammonoosuc	975	1,670
Passumpsic	1,660	--
Wells	--	120
Mascoma	895	4,100
Sugar	1,870	8,615
Ashuelot	2,240	5,360
White	650	750
Ottaquechee	170	--
Black	1,085	910
Williams	85	--
Sacketts Br.	--	2,020
Saxtons R	--	400
West	135	--
Connecticut	5,145	3,710
TOTALS	15,645	181,655

[1] Upstream of Northfield Mountain intake.

Of the totals shown in Table 6, only about 1% of the load was removed in 1960. Since that date, several municipal treatment plants have been constructed and are now operating. The impact of these plants, however, has not decreased to a significant degree the waste loads in the Connecticut River.

Pollution loads from the upstream rivers and brooks are subject to the natural purification processes of the river itself. Studies conducted as part of this report, however, reveal major sources of pollution presently exist in close upstream proximity to the diversion intake. The largest single pollution source upstream is the Ashuelot River.

Waste discharges into the Ashuelot originate from both municipal and industrial sources. Included in the industries now discharging into the river are woolen mills, leather factories and paper product industries. Based on an average over the past ten years, over 8% of the Connecticut River flow at the proposed diversion intake is flow from the Ashuelot.

The Environmental Protection Agency, in cooperation with the New Hampshire Water Supply and Pollution Control Agency and the Vermont Division of Water Supply and Pollution Control, has established an implementation schedule for abatement of all point sources of pollution upstream from the diversion intake at Northfield. This implementation schedule calls for secondary waste treatment facilities to be constructed and in operation by 1976. Adherence to this established schedule is vital to the quality of the Connecticut River water which is to be diverted for water supply purposes. If the schedule is not adhered to, the potential for increased pollution loads hindering the use of the river as a water supply source is a strong possibility.

23. Multi-Purpose Applications

As noted in the description of the project facilities, the majority of the construction required for the water supply diversion would be a deep rock tunnel aqueduct. The possibility of incorporating other allied water uses is, therefore, quite limited on the diversion facility itself.

Construction of the aqueduct and outlet facilities would necessitate the establishment of haul and construction support roads. Following construction, these roads would provide limited access for recreation, hiking, camping, hunting, and fishing. Because Quabbin Reservoir

acts as a primary reservoir for communities in the Chicopee area, however, it is uncertain as to the extent which these activities would be allowed by the responsible State Agency.

At present, recreational activities on the receiving storage reservoir for the diverted Connecticut River flow, namely Quabbin, are limited. Under sanitary rules and regulations established by the Massachusetts Department of Public Health, bathing in the Metropolitan District Commission's storage and distribution reservoirs is prohibited.

Under special rules and regulations, the use of boats at Quabbin Reservoir for fishing purposes is permitted. Three boat mooring areas are maintained by the MDC on the reservoir and outboard motor boats are rented during the fishing season. In addition, shore fishing is permitted on the reservoir from three locations. Although full attendance records at these controlled recreation locations are not maintained, the reservoir Superintendent estimated that the facilities provided opportunities for 250,000 visitor days in 1971.

The volume depletion of Quabbin Reservoir, anticipated if additional sources are not made available, will cause environmental damage to the reservoir. One form this damage may take is the reduction of the managed fisheries program in the reservoir. If this occurred, the present recreational usage of the reservoir would undoubtedly suffer. The provision of additional volume to the reservoir through the diversion project thus will preclude some of the recreational opportunities lost.

Recently, a number of fish and game clubs, watershed associations and other groups have requested that the reservoir and its watershed be opened further to recreational pursuits. In response to these requests, the MDC has stated they are willing to consider specific proposals in conjunction with approval of the health authorities. It appears then that increased opportunity for recreational usage can be anticipated. The role which the diversion project itself would play in any increased usage would lie in its potential for preventing damage to the reservoir and loss of these future recreation opportunities.

24. Monitoring Program

Throughout the history of the Metropolitan District Commission water supply system, a policy of strict watershed management has been used as the first line of defense in maintenance of good quality water. Now, for the first time, water from a watershed not directly or

indirectly controlled by the MDC will be introduced into the main storage reservoir of the system.

The Connecticut River's water quality is subject to many factors, both natural and man-made. To insure then that the introduction of this water will not impair the existing good quality reservoir water, it is imperative that a carefully designed monitoring program be established.

Within the detail of this report, it is not possible to determine totally the full requirements for such a monitoring program. That degree of detail belongs rightfully in the design phase of the project.

Even without the benefit of such detailed analysis, however, it is apparent that monitoring programs must be established at least in three locations. These are: 1) in the Connecticut River upstream of the diversion intake such that representative samples of river water to be withdrawn can be evaluated; 2) in the upper reservoir of Northfield Mountain so that water to be diverted to Quabbin Reservoir can be tested and analyzed; and 3) within Quabbin Reservoir itself such that any potential impact of the diverted flow on the reservoir or on the water quality delivered to consumers can be readily recognized and dealt with.

Provisions for these monitoring activities should be fully prepared and operational before the actual diversion occurs to provide background data and operational experience.

SECTION VIII

ESTIMATES OF FIRST COSTS AND ANNUAL CHARGES

25. First Costs

The total estimated cost of the water supply facilities at the Northfield Mountain upper reservoir, connecting tunnel aqueduct to Quabbin Reservoir and outlet works is $46,815,000, based on July 1974 price levels. Estimates of costs for the already completed upper reservoir works, including the raising of the dikes and intake tower, were supplied by the Metropolitan District Commission. Tunnel and outlet costs are of feasibility detail and developed by members of the New England Division. Estimates of construction costs were prepared utilizing a computerized tunnelling program [1] which costed both the machine tunnelling method (MOLE) and the conventional drill and blast method with the costs shown assuming the MOLE technique. All costs were based on the input of the assumed geologic conditions which controlled the design functions, with labor, equipment and material rates being costed on the basis of ENR quarterly reports including a 5 percent profit and a 25 percent overhead margin. No allowance has been made in the computer program for cost of headworks other than the discharge structure at Quabbin Reservoir. The estimated costs for engineering and overhead are based on knowledge of the site and experience on similar projects. A summary of construction costs for the project elements is presented in Table 8.

A. Available Geologic Data

Geologic information pertinent to the project was obtained from a literature survey correlated with available data from the design of the Northeast Utilities pumped power project and preliminary geologic investigations conducted by MDC along the proposed route. No exploratory data was available; however, strength tests conducted

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[1] A computer program for estimating costs of hard rock tunnelling (COHART) prepared by Harza Engineering Co., 400 West Madison Street, Chicago, Illinois - May 1970, for the Office of High Speed Ground Transportation, Urban Mass Transportation Administration, Department of Transportation, Washington, D. C., 20591, (Modified by NED).

on rock cores for the Northfield Mountain Project were utilized. Indicated rock structure and conditions are those depicted on a Preliminary Geologic Structure Section along the proposed Northfield - Quabbin Tunnel dated March 7, 1972, prepared by MDC (not included). Rock formations crossed by the tunnel alignment are comprised of approximately 85 percent hard, gneissic varieties and 15 percent softer schistose types. Inflow estimates and conditions of the rock structure (RQD) were estimated from known properties of similar rock formations on other projects. The rock formations and their assumed engineering properties are shown on Tables C-1 and C-2 in Appendix C. Critical geologic structures such as fault lines and buried valleys whose conditions and limits are unknown and assumed to be moderately severe and have been costed accordingly.

B. Proposed Tunnel Alignment

The proposed alignment, shown on Plate No. 11, represents the scheme shown on an April 1972 Plan by the MDC Construction Division entitled, "Quabbin Water Diversion Facilities -- Plan of Borings," File Cont. C-390 G 3.36 P.M. All stationing is based on a NED profile used for the computer program.

Four shaft locations selected by MDC were located and are described as follows:

Shaft 1. Located at the upper reservoir of the Northfield Power Project. Coordinates N 587,465.785 and E 347,405.915 at Station 15+00. This shaft is costed as an 18-foot, 8-inch finished diameter shaft having a 12-inch minimum thickness concrete lining with an invert elevation of 300 and a top elevation of 950 m.s.l. Two excavation schemes were estimated using a conventional and mole system with the excavated material being removed through Shaft 2. Cost estimates shown are for the MOLE technique.

Shaft 2. Located adjacent to the easterly banks of the Millers River at approximately Station 45+00. Tunnel invert elevation is at 300 m.s.l. with a ground surface elevation of 440 m.s.l. Shaft 2 is designed as a 14-foot finished diameter with a 12 inch thick lining in accordance with MDC criteria. Shaft 2 will service the tunnel west to Shaft 1 (Station 15+00) and east to Shaft 3 (Station 200+00). Disposal of all material is considered to be within a radius of two miles of the shaft requiring a disposal area of approximately two acres 30 feet deep.

Shaft 3. Located adjacent to Depot Road at Station 200+00, this shaft is 520 feet deep with a tunnel invert at elevation of 440 m. s. l. Shaft diameter is 14 feet, finished diameter, with a 12-inch thick lining. Shaft 3 will service the tunnel easterly to Shaft 4 (Station 385+00) and all material removed from Shaft 3 will be disposed of within two miles of the shaft in a two acre area approximately 30 feet deep.

Shaft 4. Located east of the Swift River and south of Morse Village, the shaft has a depth of 370 feet with an invert at elevation 440 m. s. l. This shaft has a 14-foot finished diameter with a 12-inch thick concrete lining. Shaft 4 will service the tunnel section between Stations 385+00 and 530+00. Disposal of material in this section is costed for a two acre area, 30 feet deep within two miles of Shaft 4.

Shaft 5. Located at Rattlesnake Hill on the East Branch of the Quabbin Reservoir, the shaft is 90 feet deep with an invert elevation of 440 feet m. s. l. A horizontal cut section at elevation 530 serves as a discharge apron and varies from a 14-foot width at the tunnel shaft to a 30-foot wide discharge apron 150 feet distance at the edge of the reservoir. It is considered that excavation at Shaft 5 will be disposed of within a 1 mile radius of the shaft.

In view of the lack of specific subsurface data, Shafts 1 through 4 are considered as being driven wet and requiring full ring steel supports for the first 100-foot depth. The remaining portion of the shaft would be supported by rock holts with a temporary wire mesh. In all cases, the required support in the first 100-foot depth is assumed to require full support equal to a tunnel in the same conditions. Below 100 feet the loading is assumed as 1/2 the stresses sustained by a tunnel in the same formation. Costing of shafts assumes that for safety reasons all supports will be installed as the excavation progresses and material costs will include preformed steel ribs with blocking and lagging in the upper 100 feet and 1-inch diameter rock bolts with wire mesh and grouting in lower section of the shaft. All costs of pumping and air conditioning in shaft construction are considered negligible.

The tunnel section, as designed by MDC, is costed as a 10-foot finished diameter tunnel with an 8-inch thick concrete lining operating at a head of approximately 475 feet with an overall length of 51,700 feet. All haulage will be done by train with a maximum slope occurring between Shaft 2 and 3 of .009 percent. Two potential fault zones and one crushed zone on the proposed alignment are costed as being done by conventional tunnelling methods with water inflows of up to 500 g. p. m. These severe assumptions require that the mole method

be modified for 1000 feet at each of these areas at an additional cost of reset up at 25 percent of the initial mole setup.

C. Tunnel Cost Estimate

A computerized estimate of construction cost for mole and conventional excavation was based on the proposed design and assumed geologic conditions along the alignment shown on Plate No. 11. Costs were based on a 5 percent profit margin and a 25 percent overhead margin with a regional cost factor of 1.2. A 1.2 factor is considered applicable for areas with a labor market having reasonable union controls and not particularly suited to underground construction or mining. Cost indices for labor, equipment, and materials are based on Engineering News Record (ENR) values for the month of July 1974.

All costs for ventilating and air conditioning were based on mean underground temperature of 55° F at the heading and the warmest eight hour daylight temperature at the ground surface of 75° based on records at Turner Falls, Massachusetts.

All structural design in the tunnel and shafts was based on the assumed geologic conditions and the proposed design by MDC. No costs are assumed for headworks or C.I. helical vanes at Shaft 1, or special structures or plugs in Shaft 2 for water supply operation. Noticeable increases will occur in segments 16, 17 21, 22, 24, and 25 where the tunnel intersects assumed faults and crushed zones in the rock. Fault zones are carried as a warning on Table 6 due to the assumed crushed conditions of the rock.

Disposal costs were computed on an area basis at a circumferential distance from the most appropriate shaft. Cost of land for disposal represents a real estate estimate of the approximate values of land for the section involved. Muck disposal configuration has been programmed to minimize construction activities within the reservoir areas. This has been done to reduce work traffic in the area of the headworks construction and to minimize contamination of the existing reservoirs.

A summary of construction costs for tunnel and shaft works by mole construction is shown on Table 7.

TABLE 7

NORTHFIELD MOUNTAIN TO QUABBIN RESERVOIR AQUEDUCT COSTS

Tunnel Cost Estimate

Labor	18,284,000
Equipment	4,116,000
Materials	4,227,000
Sub-total	26,627,000

Shaft Cost Estimate

Labor	3,167,000
Equipment	1,175,000
Materials	630,000
Sub-total	4,972,000

Sub-total	31,599,000
Contingencies	6,320,000
	37,919,000

26. Annual Charges

Average annual costs, summarized in Table 8, are based on interest rates of 5.875 percent for Federal and non-Federal costs. Investment costs for the project are amortized over a 50-year economic life. Annual charges for use of the facility and the power necessary to operate the diversion were supplied by the Metropolitan District Commission.

The Facilities Charge includes all items attributable to the water supply operation of the Northfield Mountain Pumped Storage Project. Such costs as the men required to operate the pumps and gates, maintenance work on the facility, heating and lighting of the facility, and part of original investment were considered in determining the Facilities Charge which was tentatively agreed to by the two parties involved, the Metropolitan District Commission and Northeast Utilities.

The Power Charge is the annual electric power costs required on an average basis to develop a yield of 72 MGD from the project. These costs were also tentatively agreed to by the MDC and Northeast Utilities.

TABLE 8

SUMMARY OF FIRST COSTS AND ANNUAL CHARGES

(1972 Price Level)

FIRST COSTS	
Water Supply Works - Upper Reservoir Northfield Mountain (Constructed)	$ 2,000,000
Tunnel Aqueduct - Northfield Mountain to Quabbin Reservoir	37,919,000
Outlet Works - Quabbin Reservoir	483,000
Total Direct Cost	$ 40,402,000
Engineering and Design [1] 9.2%	3,533,000
Supervision and Administration (7.5%)	2,880,000
Total Project First Cost	$ 46,815,000
Interest During Construction	4,126,000
Investment	$ 50,941,000
ANNUAL CHARGES	
Interest and Amortization	$ 3,176,000
Facilities Charge [2]	241,000
Power Charge [2]	666,000
Total Annual Charges	$ 4,083,000

[1] Does not include upper reservoir works which have already been constructed.

[2] At the Northfield Mountain Hydroelectric Facility.

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SECTION IX

PROJECT IMPACT ANALYSIS

24. General

A. Background

This section of the report will deal with an evaluation of the social impacts which the construction of the proposed water supply project would have. The objectives are to determine and evaluate the potential beneficial contributions as well as neutral or adverse effects which the project's development may have. These effects are evaluated in both the source and service area. Impacts are quantified and translated into dollar values where possible. In areas where impacts are not quantifiable, the effects of diversion are discussed so that the reader will be aware of all the ramifications of implementing the projects. Every effort has been made to consider all significant effects of the proposed diversion, for even the more subtle changes to a stabilized community can have important and long lasting implications.

A data baseline was first established so that changes which would occur without the proposed diversion could be measured. The baseline data in the short term are merely extrapolations of existing trends. For example, it has been assumed that in-and-out migration patterns will continue, that no major economic shifts will occur and that existing regulatory policies and jurisdictional lines will remain unchanged. Beyond the short term projections, anticipated development became less clear. Social expectations tempered by judgmental decisions have produced as reasonable projections as possible. Specifically, population, water use, and development expectations were taken from available master plans of cities and towns affected. Where no such data were available, projections of economic activity were estimated.

Impacts directly from constructing the project were based on engineering plans and site maps. To relate construction activities to impact categories, estimates were made of labor demands and capital expenditures as well as the physical alterations to specific sites relating to human activity.

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In evaluating the projects, guidelines given in Senate Document 97 were followed. In addition, the proposed Water Resources Council guidelines [1] were followed and benefits as well as losses were evaluated on a three account system. The guidelines were established under the premise that the over-all purpose of water and land re-planning is to reflect society's preference for attainment of the three objectives defined as:

1) To Enhance the National Economic Development by increasing the value of the nation's output of goods and services and improving the national economic efficiency.

2) To Enhance Environmental Quality by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems.

3) To Enhance Regional Development through increases in a region's income; increases in employment; distribution of population within and among regions; improvements in the region's economic base, and educational, cultural, and recreational opportunities; and enhancement of its environment and other specified components of regional development.

A complete accounting of relevant beneficial and adverse effects are presented as they relate to the above social objectives.

Beneficial and adverse effects are measured in monetary terms for the national economic development objective and the regional income component of the regional development objective and for some social factors.

Other beneficial or adverse effects are measured in non-monetary terms for components of the environmental quality, for the non-income components of the regional development objective, and for most social factors. Estimating these beneficial and adverse effects is undertaken in order to measure net changes with respect to particular objectives that are generated by the project. The beneficial and adverse effects on social factors are also displayed in the system of accounts.

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[1] Federal Register, Volume 36, No. 245, Part II, Water Resources Council - Proposed Principles and Standards for Planning Water and Related Land Resources.

Thus, there are beneficial and adverse effects for national economic development, environmental quality, and regional development objectives and beneficial and adverse effects on social factors. These are measured in quantitative units or qualitative terms appropriate to a particular effect.

The multi-objectives are not mutually exclusive with respect to beneficial or adverse effects, and decisions as to the selection of the recommended plan have been made by considering the difference in the effects of the alternative plans.

B. Parameters Used in the Benefit/Cost Analysis

1) Discount Rate - A discount rate of 5-7/8 percent was used throughout the computations. This is a rate furnished by the United States Office of Management and Budget. The rate reflects the average price being paid for money borrowed by the government.

Impacts were estimated on a year by year basis into the future. The capital dollar values were brought back to year 0 using present worth single payment factors to get a capital dollar value at year 0. These capital dollar values at year 0 were then amortized over the life of the project to put them into annual dollar values.

2) Project Life - A 50-year project life was selected as best fitting the circumstances of type of projects under consideration. Although the projects under consideration will not meet Eastern Massachusetts' needs 50 years into the future, it is expected that they will remain operative and be contributing to the system at least up to 50 years in the future. Consideration was given to using a somewhat longer project life, but such a course of action would contribute little for three reasons. First, projections of population and water consumption become extremely uncertain when carried into so distant a future. These projections are a basis for loss and benefit computations. As a matter of fact, loss totals enjoying a high degree of confidence end about 1990. Second, future technology, an unknown quantity, may very well make new sources of water supply competitive with the system as we now know it. Third, calculations beyond 50 years yield very little in the way of dollar amounts when figures are brought back to present worth. For instance, a $1.00 value at year 51 is worth only $0.06 when brought back to year 0. The $1.00 at year 100 is worth only $0.004 when brought back to year 0.

The year 1976 was selected as the year in which the project could possibly go into operation. This is year 0 in the 50-year economic life.

3) Price Level - The price level established for this study was based on the prevailing prices in 1974. No changes in this price level were considered during the life of the project. This assumption, although not supportive by historical record, should not lead to any erroneous conclusions because, in general, the rate of price level increases in the past has tended to be uniform among the various facets of the economy. There is no reason to suspect that the rate of price level change in the donor area, receiver area, or New England region would vary significantly from the national average.

Benefits and adverse effects of the project have been determined by comparing the conditions expected with the plan to the conditions expected without the plan. In other words, impacts are defined as deviations from the no-project baseline. The term "no-go situation" in the following paragraphs is defined as the state of affairs which will prevail if the existing water supply system is not augmented with additional water from any source. The "go situation" conversely is the situation which will exist if the particular alternative in question is implemented. The no-go situation, therefore, becomes a baseline for comparison of the various alternatives.

C. Elements Included in Analysis

1) General - A contract was negotiated with a private concern to make a study and report on the social and economic impacts of diverting water from the Millers and Connecticut River Basins into the Eastern Massachusetts water supply system. The report[1] which evolved from this study is included in this report as Appendix F. This work, which can best be described as a case study, first established the existing socio-economic framework in which the proposed water supply development will be acting. After establishing this baseline situation, the contractor then determined the positive and adverse effects which could be expected if the water supply developments were to be constructed.

Budgeting and time constraints on the study made it impossible to do a complete economics analysis under contract. The contract was negotiated midway through the NEWS Study and final alternative plans had not been decided upon; in fact, results of the study could have changed the direction of the investigation. With this in mind, it was decided that the money

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[1] Identification and Assessment of Social and Economic Impacts of the Connecticut and Millers River Basin Diversions - Abt Associates, Inc., June 1972.

spent under contract would be used to the best advantage if an intensive study were made on the Northfield Mountain Project and on one specific alternative on the Millers River Basin. The contract work was then used as the basis of in-house study of further alternatives and evaluations under the other two accounts. Regional Development was selected as the account to be addressed by the study.

This approach worked out very well. Impacts on the receiver area depend primarily on the quantity and timing of deliveries to the system. It makes little difference where the water comes from. If the study had taken a drastic change of direction and some different source of water emerged as a better alternative, the contract work would have been a valuable reference; because although values would change, the methodology would be no less valid.

2) Economic Loss Categories - Economic losses estimated in this report as a result of supply shortage may be described either as one time events or happenings on an annual basis. In the former category belong all losses connected with investment projects undertaken to either permanently increase the supply of water available to an area or to permanently decrease the consumption rate. Once such investment projects are undertaken, the losses that formerly resulted will not be experienced again unless the shortage grows more severe. Altogether, seven types of concrete losses were analyzed in this study. The Contractor gathered information in the field and made numerous telephone inquiries. He also relied heavily on collected data and methodologies developed under a study for Resources for the Future, Inc.[1]

LOSS TYPE 1

Annual Loss Categories: Industrial Sector.

Two major subheadings fall in this category:

(1) Business losses resulting from forced slowdowns or shutdowns in production due to drought; and

(2) Disparate costs, like dry-hole wells, cloud seeding, and water conservation programs. The magnitude of these losses was

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[1] Drought and Water Supply, Russell et al, Johns Hopkins Press, Copyright 1970.

estimated first at lost value added for shutdowns and forced slowdowns, and then as the costs of the various "other" projects.

LOSS TYPE 2

Annual Loss Categories: Municipal Sector.

The subheadings distinguished here include:

(1) Lost Revenue on water not sold (the prevailing price of water times the shortage computed as the difference between potential demand and available supply);

(2) Emergency Supply Costs, based on interviews with water systems managers and press accounts;

(3) Other, the "costs of redistributing the town's available water in a desired pattern as in hiring spray trucks to cart river water to thirsty trees and shrubs," and certain investment projects which ought to be classified as permanent losses; for example, the costs of "a well for a town swimming pool . . . . . efforts to find new groundwater sources, etc." For the purpose of this study, the "Municipal Other" category is treated as an annual cost because it has been impossible to split apart this category into its appropriate investment and annual components.

(4) Tree Losses, these losses reflect the town's inability to water trees as a result of shortage.

LOSS TYPE 3

Annual Loss Categories: Revenues Lost to Municipal Sector.

Included here were the losses of municipal revenue on water that the town was not able to sell because of the restrictions. Markup margins on water purchased from the Metropolitan District Commission (MDC) were estimated on the basis of a telephone survey of the sample town's water departments. Not included here are the revenues lost by the MDC system itself; this category includes only the markup lost by the client municipalities.

LOSS TYPE 4

Annual Loss Categories: Commercial Sector.

As in the industrial sector losses include:

(1) Business Losses, and

(2) Projects aimed at reducing consumption. This section consists of non-manufacturing establishments, including firms engaged in trade and services.

LOSS TYPE 5

Annual Loss Categories: Domestic Sector.

The only subheading falling in this category consists of sprinkling losses, the losses of consumer surplus resulting from a complete or partial ban on lawn sprinkling.

LOSS TYPE 6

Permanent Losses: Industrial Sector.

The only heading here reflects the claimed costs of all permanent water-use adjustments . . . . . (such as) cooling towers for the recirculation of cooling water; wells drilled to increase the plant's independent supply capability; process-water recirculation systems; additions to existing dams; new dams; installations of air-cooled window air-conditioners, and others.

LOSS TYPE 7

Permanent Losses: Domestic Sector.

Like industries, certain households made emergency investments in order to shield themselves from the effects of drought. There appears to have been no domestic investments undertaken to control consumption (i. e., recycling), and investments which were undertaken to provide new, independent sources of water appear not to have been profitable. This implies fairly large losses for this sector.

Permanent Losses: Other Sectors.

Investments of varying profitability were undertaken by sectors outside of the industrial and the domestic sectors, however, these investments

were quite small. It was felt that they would be best handled as annual impacts.

One aspect of these losses deserves special consideration. Can losses for a number of firms be summed up and expressed as losses for the industrial sector as a whole? For example, in a hypothetical situation where a serious labor shortage exists, losses of value-added in industries forced to restrict operations due to water shortage may be cancelled by gains in value-added by industries which profitably hire the labor released. In this study, it has been assumed that all value-added is lost when a firm is forced to shut down its operations. It is possible to look at the entire system shortage and make a series of alternative assumptions by which people and resources can be transferred either to non-water-dependent production units or to production units outside the shortage area. In this way the system losses can be, in fact, less than the full losses of firms suffering the shortage; therefore, in instances where we are working with estimates of the cost of shortage in the region, no benefits are reaped from stimulation occurring in non-shortage areas or in non-water using activities outside the region as a consequence of the slowdown.

3) Socio-Economic Impact Categories - Impact categories used to measure effect of the project's construction are shown in Table 9. The measures they include, because of lack of data, are in some cases at too fine a level of detail. The categories shown, however, were used to the greatest extent possible in attempting to define socio-economic impacts in both the Connecticut River Basin and the Boston Metropolitan Region.

4) National Economic Development - The National Economic Development (NED) objective is enhanced by increasing the value of the nation's output of goods and services and improving the national economic efficiency. Entries under this account can, of course, be either positive or negative. Any item under this account will be carried under one or both of the other two accounts (Regional Development and/or Environmental Quality). The converse is not true. An example is in order.

Suppose an item, say a paper product, is not manufactured in the region of a proposed project because of a drought situation. This would create a loss in the regional economy. If the lost production were made up elsewhere in the United States, then there would be no loss in the NED account. If, on the other hand, the paper product was a specialty of the region that was effected and could not be manufactured elsewhere, then the loss would

TABLE 9

SOCIO-ECONOMIC IMPACT MEASUREMENT

Impact Categories	Suggested Measures	Units	Time Period
1. Land Use	Net change in the percent distribution of acres devoted to industrial, commercial, agricultural, residential & recreational uses.	Percent	Long
	Net change in land use caused by the various physical diversion facilities (e.g., dams, pipelines, tunnels).	Acres	Short & Long
	Net change in the amount of land available for development.	Acres	Long
2. Population	Net changes in the age, income, race and ethnicity distributions of the local population, particularly in the donor areas.	Percent	Short & Long
3. Municipal Finance	Loss of assessed valuation as a percent of community total.	Percent	Long
	Increase in assessed valuation resulting from improved water service.	Dollars	Long
	Net change (gain/loss) in tax revenue resulting from improved water service.	Dollars	Short & Long
4. Commercial Activity	Net change over normal trends in gross wholesale and retail sales of those facilities affected by availability of water resources.	Dollars	Short & Long
	Net number of businesses located (displaced) by a facility	Number	Short & Long

TABLE 9 (cont'd)

5. Housing	Net change (increase/decrease) in number of housing units by number of bedrooms by price (OR).	Number	Short
	As a percent of community's total stock in the receiver area.	Percent	Short
6. Education	Net change in amount of classroom and other educational space required for projected change in school-age population resulting from in- and out-migration.	Sq. Ft.	Short & Long
	Net changes in cost of teacher and other education staff required for projected change in school-age population resulting from in- and out-migration.	Dollars	Short & Long
	Net change in cost of providing school services because of changes in busing.	Dollars	Short
	Use of facilities for educational programs.	Day/Yr.	Short
7. Leisure Opportunities	Net change in the total number of acres of parks and playgrounds in the Study Area.	Acres Visitor Days	Short & Long
	Net change in the extent to which planned recreation space meets American Society of Planning Officials planning standards relating types of space to population characteristics.	Percent	Short
8. Cultural Opportunities	Total number of churches, historical sites or other cultural institutions taken.	Number	Short
	Cost of relocating churches, historical sites and other cultural institutions, minus compensating payments.	Dollars	Short
	Increase in locational amenities (e.g., improved site planning, additional parking, etc.) as a result of relocation.	No. of Improvements	Short

TABLE 9 (cont'd)

9. Transportation	Net change in travel time as a result of facilities from major residential areas to activity centers: health, commercial, recreation, employment, education, cultural	Min./Trip x Trips/day	Short
10. Municipal Services	Net change in cost of providing water, sewerage, and garbage service and other municipal services. Net change in residential insurance rates.	Dollars Percent	Short & Long Long
11. Security	Number of positive and negative statements about the opportunities for system failure, as revealed by a content analysis of local news media.	Number	Short & Long
12. Community Image	Changes in property values adjacent to supply facilities Number of positive and negative statements about the community as revealed by a content analysis of local news media.	Dollars Number	Short & Long Short & Long
13. Community Cohesiveness	Total number of community, regional, statewide and national groups taking a position (making a public statement) for or against the project.	Number	Short
14. Citizen Involvement	Total number of community, regional, statewide and national groups involved in the planning of the project, times the level of their involvement, according to the following scale of increasing involvement: 1. Attendance at hearing; 2. Citizen opportunity to critique plans at public meetings; 3. periodic workshop planning sessions with community representatives; 4. community advocate planner participated on equal basis with technical staff in all planning activities; 5. appointment of arbitrative hearing officer who makes final decision in case of dispute between community & Army Engineers.	Weighted No.	Short

TABLE 9 (cont'd)

15. Institutional Involvement	Total number of jurisdictions involved in the totality of the construction process for a water supply facility.	Number	Short & Long
	Number of applications submitted to the MDC for water supply service by cities and towns; disposition and frequency of refusal.	Number	Short & Long
16. Economic Stability	Net change in income resulting from construction and related activities.	Dollars	Short & Long
	New increase in private investment.	Dollars	Short & Long
17. Real Income	Net change in per capita income.	Dollars	Short & Long
	Net change in tax assessments.	Dollars	Short & Long
	Net change in regional net income.	Dollars	Short & Long
18. Employment	Number and type of jobs created/lost.	Number	Short & Long
19. Industrial Activity	Change (increase/decrease) in number of industrial establishments.	Number	Short & Long
	Change in productivity indices.	Dollars	Short & Long
20. Agricultural Activity	Change (increase/decrease) in number of farm acres.	Number	Short & Long
	Change in production per acre.	Dollars	Short & Long

occur in the NED account as well as the regional account. Following the logic further, if other manufacturers outside the region manufactured the product but were operating to capacity, then they could not take up the lost production. The lost production would not be made up in the United States and the loss would be to the region as well as the NED account. The same logic can be applied to an item which is part of the environmental quality account.

It is quite possible that only a part of a regional or environmental account entry will appear in the NED account. Example, a loss in the region that will be only partially mitigated elsewhere in the country.

In this study, as described earlier, seven economic loss categories were used to determine the economic impact of water shortages. All of these categories express losses to the regional development.

Upon examining the losses in each category, it was decided that losses in four of the categories; Municipal Emergency Supply and Other, Municipal Lost Revenue, Domestic Losses and Domestic Investment would be carried 100% into the NED account. It was decided that the remaining three; Industrial Business Losses and Other, Commercial Losses, and Industrial Investment would net out to zero (mitigated in full by the national economy). Industrial Investments are assumed to operate at no loss; therefore, losses were 0 in both accounts.

Based on the above procedure, then, the method for determining NED losses was to remove Commercial Losses and the Industrial Business Losses and Other from total Regional Economy Losses.

5) Environmental Quality - In assessing the impact of the project on the environment, contractor services as well as in-house personnel were used extensively. An evaluation was made of the project's impact on the Connecticut River estuary; on the Connecticut River; on the environment of the receiving water storage reservoir, i. e., Quabbin; and the Boston Metropolitan Region. Full descriptions of these investigations are included later, and in Appendices D and E.

6) Regional Development - In assessing the impacts which the project's implementation might have on regional development, a subdivision into two groupings of communities was required. This subgrouping was necessitated because any impact of the diversion on Connecticut River Basin communities (or source area) would be keyed to

the withdrawal of water from the basin. On the other hand, communities supplied by the water would experience a separate set of impacts from any of the alternatives.

A determination thus was made as to what, in fact, were the supplier and receiver communities sub-groups. It was decided that only the communities directly affected by the project would be considered as suppliers. It became clear that social and economic impacts in the Connecticut Basin would be most significant for site-specific activities. Communities such as Deerfield and Leominster would probably be slightly affected by the project, however, not to a point that could be quantified or even speculated upon reasonably. Greenfield, Erving, Royalston, Warwick, Athol, Winchendon, and Orange are the only communities that would be noticeably affected by this project and projects in the Millers River Basin. Environmental studies presented in this report indicate that downstream communities on the Connecticut River, as well as the Connecticut River estuary, would not be significantly affected from an environmental or ecological standpoint. On this basis, it was decided not to include these communities among the suppliers. A complete listing of all communities examined as potential suppliers is given in Table 10.

Receiver communities are defined as present recipients of the Metropolitan District Commission Water Supply System plus those communities which will have no other reported engineering option than to join the system to meet their 1990 water supply needs. The sixty-six receiver communities are given in Table 11.

28. Evaluation

A. Regional Development Account

1) General

As described earlier, impacts from the implementation of the project on the regional development within the study area received considerable attention. Included in this analysis was an assessment of the project's impact on the socio-economic objectives of communities both within the basin (or suppliers) from which water would be diverted as well as communities which would be supplied by the diverted flow (or receivers).

To impose some rational structure of the impact analysis, the study was structured in a matrix fashion. The project together with the baseline "no-go scenario," was considered with respect to each relevant impact category shown in Table 9. By considering the project in this fashion, an evaluation of the project's economic and social change and the no project baseline was possible.

Obviously, not every possible combination is equally important. In some cases, the magnitude of change in a given impact category is so small as to be insignificant. In others, a forecast change may be small but long-lived, thus overshadowing a larger but more ephemeral effect. Generally, the effort was made to distinguish short- and long-term changes for each impact category as it relates to communities. Short-term has been defined as the five-year term required for construction. Thus, impacts so accounted are project-specific. Long-term encompasses changes falling outside that limit and related less to the specific works proposed than to the shortage/availability of a quantity of water equal to that diverted. In both cases the definitions apply without regard to real time; that is, the five-year period begins to run whenever construction commences.

If implementation of the project is delayed an inordinate period of time, then the impacts as described, of course, became less valid. A delay of 10 years, for example, would place communities served by the regional system in a precarious water supply situation.

The total number of communities examined totalled eighty-four. Of this number, eighteen were considered potential suppliers or municipalities from whom water would be diverted. The balance of sixty-six municipalities or communities which would use the water were considered as receivers. A listing of the municipalities included in the supplier and receiver sub-groups is given in Tables 10 and 11.

Insofar as possible, profiles of sample communities were built in the same format as impact categories described in Table 9. Over the short term, baselines are merely a continuation of trends noted in the profiles. For example, it has been assumed that in- and out-migration patterns will continue, that no catastrophic economic shifts will occur and that existing regulatory policies and jurisdictional lines will remain unchanged. Over a time horizon extended to fifty years, however, anticipated development is less clear. However, the study made use of the best projections available. Specifically, population, water use, and development expectations have been taken from the available Master Plans of cities and towns affected. Where no such data were available, projections of economic activity were developed. In all cases, impacts are defined as deviations from the no-project baseline.

TABLE 10

SUPPLIER COMMUNITIES

Ashburnham	Northfield
Athol	Orange
Deerfield	Petersham
Erving	Phillipston
Gardner	Royalston
Gill	Templeton
Greenfield	Warwick
Hubbardston	Wendell
Montague	Westminster
New Salem	Winchendon

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TABLE 11

RECEIVER COMMUNITIES

Fully Served Members

Arlington	Malden	Quincy
Belmont	Marblehead	Revere
Boston	Medford	Saugus
Brookline	Melrose	Somerville
Chelsea	Milton	Stoneham
Everett	Nahant	Swampscott
Lexington	Newton	Waltham
Lynnfield	Norwood	Watertown
		Winthrop

Partly Served Members

Cambridge	Wakefield
Canton	Weston
Needham	Winchester
Peabody	

Served Non-Members

Clinton	Lancaster	Northborough
Chicopee	Leominster	Southborough
Framingham	Marlborough	South Hadley
		Wilbraham

Communities with No Other Option

Ashland	Hudson	Sherborn
Avon	Lincoln	Stoughton
Bolton	Maynard	Stow
Braintree	Medfield	Sudbury
Dedham	Millis	Wellesley
Dover	Natick	Westwood
Holbrook	Norfolk	Weymouth
Holliston	Randolph	Woburn

2) Methodology

Because individual treatment of each of the eighty-six communities (source and receiver) affected by the proposed projects was never considered feasible within the dollar and time constraints of the study, it was necessary to limit the number investigated. Therefore, a computerized clustering exercise was performed which grouped communities according to sixteen descriptors:

(1) Present Population
(2) Projected Population
(3) Population Growth
(4) Population Density
(5) Employment
(6) Median Income
(7) Present Water Demand
(8) Projected Water Demand
(9) Status of M. D. C. Service (served, non-served)
(10) Total Industrial Demand
(11) Restrictions on Consumption (yes, no)
(12) Supplier or Receiver
(13) Future M. D. C. Member
(14) Present M. D. C. Member
(15) Served Non-Member
(16) Have No Option

Next, one element from each of the sixteen resulting clusters was chosen for further study. In the subsequent data gathering effort, it became clear that not every sample community had the data required to establish competent socio-economic profiles, or more importantly, Master Plans from which to extract expectations of future development. Supplier towns, with the exception of Greenfield, were particularly data-poor. Indeed, they were omitted from a second clustering program which was then run for only the sixty-six receivers.

It appeared from preliminary work that long-term economic impacts were going to be most important in receiver communities. Therefore, the variables chosen for the second clustering program were restricted to economic factors suggestive of uniform economic structure. The outputs of this second program are as follows:

CLUSTER 1.

Elements: Arlington, Revere*, Saugus, Winthrop, Weymouth

Representative and Descriptors:

Revere*

Low-income area
Urban/Boston satellite, North
Largely residential
Commercial economy
Stagnant or little growth potential
Low water user
MDC receiver

CLUSTER 2.

Elements: Belmont*, Brookline, Milton, Swampscott, Lincoln, Lexington, Newton, Nahant, Needham, Wellesley

Representative and Descriptors:

Belmont*

High-income area
Urban/Boston suburb or satellite
Residential
Commercial economy
Moderate growth rate
Low water user
MDC receiver

CLUSTER 3.

Elements: Boston*, Cambridge, Maynard

Representative and Descriptors:

Boston*

Low-income to poor area
Urban/city core
Increasingly less residential
Mixed economy; larger proportion commercial
Stagnant to negative growth rate
High water user
MDC receiver

CLUSTER 4.

Elements: Chelsea, Everett, Peabody*, Clinton, Chicopee, Ashland, Woburn

Representative and Descriptors:

Peabody*
- Low-income area
- Urban independent/North Shore
- Highly industrial
- Moderate growth rate
- High water user
- MDC receiver (very small % of total consumption)

CLUSTER 5.

Elements: Lynnfield, Marblehead, Weston, Winchester, Southborough, Dover, Holbrook, Medfield*, Stowe, Westwood

Representative and Descriptors:

Medfield*
- Moderate or middle-income area
- Rural/Southwest of Boston
- Largely residential
- Mixed economy; moderately industrial
- Stagnant or low growth potential
- Low water user
- Not an MDC receiver

CLUSTER 6.

Elements: Malden, Medford*, Somerville, Stoneham, Lancaster, Watertown

Representative and Descriptors:

Medford*
- Moderate or middle-income area
- Urban/Boston satellite or suburb
- Residential
- Economy mostly commercial
- Stagnant or low growth potential
- High Water user
- MDC receiver

CLUSTER 7.

Elements: Melrose, Marlborough, Wilbraham, Holliston, Hudson, Randolph*, South Hadley, Millis, Stoughton

Representative and Descriptors:

Randolph*
- Moderate to middle-income
- Urban independent/South of Boston
- Moderately residential
- Mixed economy - highly industrial
- High growth potential
- Low water user
- Not an MDC receiver

CLUSTER 8.

Elements: Wakefield, Norwood, Framingham, Natick*, Leominster

Representative and Descriptors:

Natick*
- High-income area
- Urban independent/West of Boston
- Moderately residential
- Mixed economy - highly industrial
- Moderate growth potential
- High water user
- Not an MDC receiver

CLUSTER 9

Elements: Canton, Avon, Bolton, Sherborn, Sudbury, Northborough*, Norfolk

Representative and Descriptors:

Northborough*
- Moderate or middle-income area
- Rural/West of Boston
- Largely residential
- Mixed economy - mostly industrial
- High growth potential
- Moderate water user
- MDC receiver

CLUSTER 10.

Elements: Quincy, Waltham, Braintree*, Dedham

Representative and Descriptors:

Braintree*	High-income area
	Urban/South of Boston
	Moderately residential
	Industrial economy
	High growth potential
	Moderate water user
	Not an MDC receiver

The subgroup of supplier communities selected for close examination were limited to seven: Greenfield, Erving, Royalston, Warwick, Athol, Winchendon, and Orange. These municipalities were chosen because early in the investigation it became clear that social and economic impacts in the Connecticut Basin would be most significant for site-specific activities, remote suppliers like Deerfield and Leominster were eliminated. Though a case could be made for examining towns downstream on the Connecticut, it was felt that the environmental studies under way would point out any important changes for these communities. From the social and economic standpoint, analysis by community outside the immediate diversion area would not have been fruitful, or even possible.

The backbone of the analysis was the projection of economic and residential activity for the receiver area from 1970 to 2020. Of the sixty-six communities total, none but a very few had themselves done any significant forecasting.

As noted above, the basic strategy was to build clusters on the basis of key economic indicators. In this way, information could be used in our analysis that could not have been obtained for all sixty-six cities in a reasonable time. While most work actually proceeded on the 66-city level, values for certain variables were estimated for cluster sample cities only and then assumed to apply also to other communities in the same cluster. Thus, when a variable could not be feasibly collected for all receivers, an estimate was made for a representative city in each cluster and assumed that its value was shared by all other members of its cluster.

Even so, information was not easy to come by, especially for the very distant years, 1990 - 2020. As is usually the case for projective studies, some very general numbers were available for the far end of the time horizon; projections prepared for New England, or at best for eastern Massachusetts. The application of such general information to particular localities has been a risky venture, however sensitively done.

Thus, the implication is that estimates presented later are likely to be far more meaningful for larger groups of jurisdictions studied (i. e., for clusters, or for the aggregate of all receivers) than for any one cluster element. This is especially true for the years near the 2020 time horizon. Accordingly, loss estimates are not presented for each individual receiver since such displays of data would be likely to contain very large errors. In a cluster, on the other hand, errors are likely to cancel, and the results for the cluster as a whole are likely to be far more reliable.

Finally, to fill out impact categories related to project - specific changes, use was made of historical data from two case study communities. In the supplier area, the Town of Northfield and its responses to a very much larger construction project at Northfield Mountain (Northeast Utilities) was used as an upper bound on similar types of changes anticipated for the alternative projects. In the receiver area, interview data provided by the Chairman of the Planning Board in Stoughton established the dimensions of change to be expected in the event of widespread water shortages resulting from a situation caused without a project being implemented. This community is generally conceded to be the most deprived of potential M. D. C. water customers and offers a good example - though admittedly over a very brief period compared to the fifty-year life attempted here - of the trends to be expected in other communities equally deprived by a failure to provide for projected demands.

In the course of data collection, some contact, direct or by telephone, was established with all seventeen sample cities and towns. In most cases, specific water-related agencies or elected officials were successfully sought out.

Conversations about the major issues of the water supply problem in metropolitan Boston and diversion plans were held with residents of both supplier and receiver areas; roughly ten in each area, half being sidewalk encounters and the others more structured interviews with private individuals known to have an interest in the project. In addition, five planning officials were approached as spokesmen for their respective

constituencies in eastern and western Massachusetts. Four were members of local Planning Boards and one headed a county planning office. Other noteworthy sources included: 1. Northeast Utilities, 2. Maine Yankee, 3. The Metropolitan Area Planning Council, and 4. The Commonwealth's Office of Regional Affairs (Department of Community Affairs), Department of Education (Research and Development), Department of Natural Resources (Division of Water Resources, Division of Water Pollution Control), Department of Public Works, Division of Employment Security (Research Department) and Department of Public Health.

3) Impact on Supplier Area

The impact categories shown in Table 12 present forecasted changes in the supplier communities. The data shown represent total impacts for the sum of individual towns actually affected. Qualitative data which is keyed by superscript letter to following sections, however, is generally applicable to all eighteen communities examined as suppliers.

It should also be noted that it has not been possible to go much beyond the short term limits of construction and deal quantitively with impacts on suppliers. Baseline projections are simply not available after 1990 and forecasted impacts are directly related to construction in most every case. Unfortunately, then, assumptions have had to be made to fill more gaps than desired, but by working within ranges, it is believed gross errors have netted out.

/a/ Land Use

Approximately 30 acres would be slated for land taking under this project. Thus land use changes are minimal.

Since existing uses are almost entirely limited to undeveloped open space and since acquisition is likely to mean controlled access, the natural character of the taking area will be preserved. In any event, the service population for the project is extremely small and significant principally in the eyes of personally affected individuals.

Apart from the recreation issue, the development potential of the host towns with the project is not thought to be threatened. Given what the towns themselves must recognize as severe geographic disadvantages for industrial growth, it is highly improbable that the sites needed to implement the diversions would ever have appreciable economic value. Their value is chiefly scenic.

TABLE 12

IMPACTS ON SUPPLIERS

Impact Category	Measures Applied to: Greenfield, Royalston, Athol, Erving Warwick, Winchendon, Orange	Northfield	No Project
1. LAND USE /a/	Net change, % distribution, by use; industrial, commercial, agricultural, residential, recreational; estimated from topo sheets	0	0
	Net use change, in acres; assuming change for all land taken as an upper limit	30 acres (Wendell, New Salem)	0
	Net change in developable land, percent of land taken	Negligible	0
2. POPULATION /b/	Net change in age, race, ethnicity distribution of local populations	None	0
	Total divergence from baseline trend	0	0
3. MUNICIPAL FINANCE /c/	Loss of assessed valuation, % of total, $130,747,427 upper limit	0	0
	Increased assessed valuation from improved water service	N. A.	N. A.
	Net change (gain/loss) in tax revenue resulting from improved water service	N. A.	N. A.
4. COMMERCIAL ACTIVITY /d/	Net change over normal trends in gross wholesale and retail sales of those facilities affected by availability of water resource	0	0
	Number of businesses displaced by facilities	0	0
5. HOUSING /e/	Net change in number of housing units. Any relocations expected to be inside supplier area	None	None

N. A. = not applicable

TABLE 12 (cont'd)

Impact Category	Measures Applied to: Greenfield, Royalston, Athol, Erving, Warwick, Winchendon, Orange	Northfield	No Project
6. EDUCATION /f/	Net change in amount of classroom space required for projected change in school-age population resulting from in-migration, upper limit	1 primary classroom	0
	Net change in cost of teacher and other staff required for projected change in school-age population resulting from in-migration; average salary @ $8,000/annum	+$8,000	0
	Net change in cost of providing school bus services because of changes in housing	U	0
	Use of facilities for educational programs, upper limit, days/year	7	0
7. LEISURE /g/ OPPORTUNITIES	Net change in total number of acres of parks and playgrounds	0	0
	Net change in extent to which planned recreation space meets American Society of Planning Officials planning standards	N. A.	N. A.
8. CULTURAL OPPORTUNITIES	Total number of churches, historical sites, or other cultural institutions taken	0	0
	Cost of relocation	0	0
	Increase in locational amenities, range	1	0
9. TRANSPORTATION /h/	Net change in travel time as a result of facilities construction	0	0
10. MUNICIPAL SERVICES	Net change in providing water, sewerage, garbage service and other municipal services	None	None
	Net change in residential insurance rates	N. A.	N. A.

U = data unobtainable at this level of detail

TABLE 12 (cont'd)

Impact Category	Measures Applied to: Greenfield, Royalston, Athol, Erving, Warwick, Winchendon, Orange	Northfield	No Project
11. SECURITY	Number of positive and negative statements about the opportunity for system failure (new facilities)	N. A.	N. A.
12. COMMUNITY IMAGE /i/	Changes in property values adjacent to supply facilities, per holding; totals small in view of limited takings		0
	Number of positive and negative statements about communities as revealed by content analysis of local news media	0	0
13. COMMUNITY COHESIVENESS (See /i/)	Total number of community, regional, statewide and national groups taking a position for or against the project	5-10	0
14. CITIZEN INVOLVEMENT (See /i/)	Total number of community, regional, statewide and national groups involved in planning of the project, times the level of their involvement, according to the following scale: 1. Attendance at hearing. 2. Citizen opportunity to critique plans at public meetings. 3. Periodic workshop planning sessions with community representatives. 4. Community advocate planner participated on equal basis with technical staff. 5. Appointment of arbitrative hearing officer (5 x 8)	0	0
15. INSTITUTIONAL INVOLVEMENT	Total number of jurisdictions involved in the totality of the construction process for water supply facilities	(2 towns M. D. C. State) 4	0
	Number of applications submitted to the M. D. C. for water supply service; disposition and frequency of refusal	N. A.	N. A.

TABLE 12 (cont'd)

Impact Category	Measures Applied to: Greenfield, Royalston, Athol, Erving, Warwick, Winchendon, Orange	Northfield	No Project
16. ECONOMIC STABILITY (See /d/)	Note change in local economic activity resulting from construction and related activities; 100 x $7,000 x 2 = value added in dollars	1,400,000	0
	New increase in private investment	0	0
17. REAL INCOME	Net change in per capita income; Net change in tax assessments per individual taxpayer Net change in regional income	No significant change anticipated	
18. EMPLOYMENT (See /b/)	Number and type of construction jobs opened; substitution effects not accounted for.		
	P: professional	30P	
	S: skilled	170S	
	U: unskilled	300U	
		500	0
	Secondary employment (.2 - .4 times total jobs)	100	
19. INDUSTRIAL ACTIVITY	Change in number of industrial establishments	0	0
	Change in productivity indices	None	None
20. AGRICULTURAL ACTIVITY	Change in number of farm (productive) areas, upper limit	20	0
	Change in production per acre	0	0

/b/ Population

Beyond the labor influx associated with construction of the project, it is highly unlikely that current downward population trends will be reversed. In the decade between 1960 and 1970, no town in the immediate supplier area registered appreciable growth; and Winchendon, Athol and Orange experienced net outmigrations of better than 250 persons each. The principal determinant of any population changes related to the diversions proposed will be the recreation issue. Should the development of recreational facilities take place, it is possible that the supplier area could see a slight increase in residential population, though probably only on a seasonal basis.

Construction-phase labor demands will have at least a temporary effect on suppliers, however. About 300 unskilled construction workers, 170 skilled, and 30 professional people would be employed directly on the project.

To determine how the combined incomes of that work force would be distributed, the experience during construction of the Northfield Mountain Hydroelectric facility was utilized. Though the project was very much larger -- $90 million, employing a total of some 3,700 persons -- the tasks required, (such as tunneling, concreting, carpentry iron working, pipe fitting, etc.), are of much the same nature as will be required on the diversion works, and project labor is likely to be drawn from the same sources. In a post-audit of the labor force assembled for construction of the pumped storage project,[1] Clark points out that of the 3,368 people employed in the crafts, fully 84% were hired locally; that is, only 16%, or 477 men moved into the area to obtain project work.[2] The great majority already lived within commuting distance and spent their paychecks locally. Indeed, aside from those immigrants who established temporary addresses for the term of their employ (principally hard rock miners from North Carolina, New York State and other extra-regional areas who were supporting families left behind), salaries were

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[1] "The Labor Force Associated with the Northfield Pumped-Storage Hydroelectric Project and Its Effects on the Surrounding Communities," Frank Clark, University of Massachusetts, January 1971.

[2] The reverse is true for supervisory personnel. Of 355 persons so employed, roughly 60% were immigrants moving to the area for the duration of the project. Most often families were settled in a population center near the project site or in trailer parks in nearby New Hampshire. In terms of spending, however, the same general patterns apply to "wage" staff as to the field force.

introduced to the economics of Central Massachusetts and southermost New Hampshire and Vermont. Thus, apart from the purchase of meals and incidentals, the salaries of both professionals and the field force were spent within the immediate region but outside the borders of the towns sharing the construction site. As for rents, the largest portion of temporary residents was set up in Greenfield or Montague, Massachusetts rooming houses, housing closer to the construction site being virtually unavailable.

Thus, if the Northfield Mountain water supply project is a "union job" and that is the supposition, the same commutation and spending patterns are likely to apply, though at reduced levels.

/d/ Commercial Activity

With a wide distribution of labor, salary spending should be well diffused, with no one city or town experiencing more than marginal increases in commercial activity. The alternative diversion projects may absorb whatever labor surplus is created by the completion of the Northfield Mountain pumped storage facility and maintain the employment status quo. Of course, since scheduling is uncertain, unemployment conditions at the time of construction are unknowable, and it is possible that the water supply project will come too late to prevent an employment sag caused by the demobilization at Northfield or offer only substitution effects -- paying salaries obtainable elsewhere in a time of full employment. At present, however, unemployment in Massachusetts is in excess of the national average with a rate of 7.5% compared to the national figure of 5.9%. In the immediate vicinity of the project in Greenfield, Athol, and Gardner, unemployment is even higher than the State total, with figures of 10.1, 7.7, and 8.5%, respectively. Unless, then, employment opportunities prior to construction alleviate these high unemployment totals, construction activities would provide substantial opportunities for employment. In any event, the diversion construction could well absorb the fifty-odd local hard rock miners trained at the hydroelectric facility.

Beyond the salaries generated, short-term economic impacts also encompass the monies paid to local residents through land acquisition. Neither the magnitude nor the distribution of such payments in readily available.

Again, as with salaries, benefits to the regional economy rather than to individuals are to be reckoned not just in terms of dollar totals, but by their fluidity. Clearly, when a land seller receives dollars for his land, it makes a difference to the community whether he saves the money, reinvests it or spends it.

Long-term economic implications for suppliers center largely around the extent to which the volumes of water diverted affect industries now located in the area. As for the first issue, comments made by industry spokesmen at the public meeting held at Athol in late October 1972 indicate a concern for maintaining flows in the Millers River [1] adequate for process purposes. However, it seems safe to conclude that no industrial enterprise will be jeopardized by high flow skimming operations on the Connecticut River and/or its tributaries. In fact, at least in the purely economic sense, the marginal value of the water to be diverted is zero. As such, it must be considered "surplus" and no tangible loss to the local economy.

/e/ Housing

During the construction period of the project, there will be an increased demand for rental housing. Probably, established urban centers at Greenfield, Gardner and Athol or Brattleboro and Keene and Hinsdale (trailers) will absorb whatever non-resident labor force appears and that towns nearer construction sites will not be affected. In no event is the stimulation of new housing construction foreseen. Housing prices and property values may rise for the term of construction but suffer setbacks when the project is completed. Since Greenfield has been identified as an area in which the housing market is sensitive, trends there should be observed as Northfield and Vermont Yankee at Vernon wind down. Adjustments will be required for any data collected to reflect the very much smaller labor force (about 500 as compared with 3,700) anticipated for this construction job.

/f/ Education

From the experience of a dozen different towns surveyed by Northeast Utilities for effects on school populations,[2] only in one, Hinsdale, was overcrowding attributed to worker influxes. It should be kept in mind, however, that the nuclear generating station at Vernon, Vermont, and increased business activity in Brattleboro account for much of that effect and obscure the influence of Northfield. Other school systems either had no marked increase in enrollments or cited natural growth rather than project in-migration as the cause of crowding.

As a conservative estimate of impacts felt in the supplier area sample of seven communities, we have used one primary classroom or about

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[1] Subject of a separate report.

[2] Bernardston, Deerfield, Erving, Gill, Greenfield, Hinsdale (N.H.), Leyden, Montague, Northfield, Orange, Warwick, Winchester (N.H.)

twenty youngsters. Noting that Greenfield appears to be a primary response area, we have located the demand there and estimate an average teaching staff expenditure of $8,400.

Busing data were not available. However, because the numbers of new school-age children to be served under the situation caused by construction activities is so small and because their distribution would likely be more general than we have assumed -- that is not just in Greenfield alone -- any change in busing costs would be extremely small.

/g/ Transportation

Impacts here are certain to be of a temporary nature. The bulk of construction is to take place below the surface with only occasional access shafts at ground level. Mobility patterns in the resident population may change to some degree, but the dominantly rural nature of the area will make such disruptions infrequent.

The construction contemplated will have almost negligible effects by comparison with the recent highway work on Route 2. Heavy trucking will be required for the removal of spoil to fill areas and the delivery of equipment, but intelligent planning can avoid traffic congestion and hazards to residents. Commutation patterns for the work force will have an appreciable effect on the traffic volumes of major arteries. Locations and magnitudes can be reckoned only after the distribution of labor has been established.

/h/ Community Image and Cohesiveness

Impacts forecasted for this category are very small. No physical separation of populations is involved, apart from temporary road closings. No aesthetically undesirable structures are planned, save in the sense that any alteration of the natural scene may be thought of by some as undesirable. Yet, it is in this category that the supply areas themselves feel themselves to be the most injured. Their perceptions of loss are very large, and some commentary seems appropriate.

In terms of standard socio-economic categories like population, density, employment, ethnicity, mobility, etc., and particularly in terms of attitudes, the immediate diversion environs are so homogeneous as to be spoken of as an entity.

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Because of the nature of the project under consideration, it is revealing to examine the source of the unanimity. Inhabitants feel that the construction of Quabbin Reservoir in the late 1930's was shock to the cultural and economic life of the area from which it has never fully recovered. As the testimony of several local people at the Orange Hearing indicated, many of the residents consider themselves refugees from the Quabbin site.

Residents of the supplier towns feel themselves to be threatened once again. That is the root of their common cause and the most important cohesive factor in their alliance against the diversion proposed. The social psychology operating here is transference; water for Boston means the bureaucratic machinery of the water supply agency, which in turn means wanton despoliation of all that local residents hold dear, and that means a repetition of the upheaval brought by Quabbin.

From the impact assessment standpoint, then, even the relatively minor changes brought about by implementation of the diversions will have two principal effects: (1) demonstrate to suppliers that their impotence has not changed in thirty-odd years and (2) draw the circle of opposition even more closely together, further alienating it from the political system dominated by Eastern interests. Supplier communities will feel themselves to have been bested yet again and withdraw into a smoldering hostility.

4) The "No Go" Scenario

In the event that the Northfield Mountain Diversion is not implemented, the single most important impact in the supplier region will be at Quabbin itself. Biological studies have determined that in the event of a near-complete drawdown, the ecologic viability of the reservoir would be endangered. Moreover, as the water area shrinks, the likelihood of odors and exposure of the unsightly bottom area grows. The recreational opportunities at Quabbin are, therefore, considerably diminished, not to mention the consequences for the receivers of Quabbin water which may change perceptibly in color and taste.

Less dramatic are the direct economic and social impacts on suppliers. First, local stimuli caused by construction activity will be zero. Whatever buffer effect the project might have had on the labor fallout at Vernon and Northfield and on unemployment in the region will be lost. Whatever dollar gains might have been realized by local economies as a result of labor force spending and landtaking costs will be foregone. It should also be pointed out that the difference between tax revenues collected on property not taken and any payments made in lieu of taxes should implementation proceed could be counted as "savings." As noted above, however, revenue data have not been made available and it can only be assumed that the amounts involved are quite small.

Finally, if the project was not implemented, whatever monetary value might accrue to the surplus waters not diverted would be returned locally. This eventuality is highly unlikely, however, because there is no reason to foresee the development of new water-dependent industry in the immediate donor area, at least in the 1975 - 1990 time frame.

5) Impacts on Receiver Area

In the receiver area, which totals sixty-six communities listed in Table 11, impacts brought about by implementation of the project can be expressed in two different ways. First, losses both with and without diversions can be totalled and compared to the costs of providing additional water from the proposed project. This comparison then provides a basis for assessing the economic efficiency of the project.

Included in the loss totals are industrial, city emergency, city revenue, commerce, sprinkling, business investment and domestic investment losses. However, these loss figures say nothing of the ways in which such losses might be allocated by the various industries and municipalities. An assessment of the potential methods which could be used to allocate these losses (utilizing the socio-economic impact categories given in Table 9) is the second method used to express losses in the receiver areas.

To measure the economic losses, a computer simulation model was developed. The model as developed investigated the consequences of a water shortage using as an information base results of a study[1] conducted during the sixties' drought in Massachusetts.

Four major sectors of the communities' economy were differentiated: industrial, commercial, municipal and domestic. A fifth sector was also

[1]Drought and Water Supply, C. S. Russell, D. G. Arcy and R. W. Kates, for Resources for the Future.

used and was comprised of various miscellaneous impacts which could not be conveniently accomodated in any of the above economic sectors. In the analysis, special care was taken to prevent double accounting of losses, that is, to make sure losses were counted in only one sector. For example, the MDC and local water departments lose considerable revenue from not being able to sell the water that is unavailable. Since this loss is charged to the MDC and local municipal sectors, the cost of the water not available to the other sectors cannot be charged as a loss to those sectors as well. Their losses should include all the damages in excess of what it would have cost them to purchase the desired amount of water.

To test the impact of water shortages, assumptions regarding the water system facilities to both average runoff and drought conditions similar to those experienced in the sixties were made. Losses associated with both runoff conditions were then calculated. Two major types of losses were distinguished: those experienced annually as a consequence of a shortage and those losses which are experienced once and for all given a certain shortage level. In the latter category belong all losses connected with investment projects undertaken to either permanently increase the supply of water available to a sector or to permanently decrease the consumption rate of the sector. Once such investment projects are undertaken, the losses that may result may not be experienced again unless the shortage grows more severe. For example, a home owner faced with a water shortage could develop an on-lot supply well to use for his lawn and shrubs. Once this investment is made, he has shielded himself from effects of shortage in future years.

Altogether seven types of losses were analyzed for their response to water shortage. These are: Annual Losses for the Industrial, Municipal, Revenues Lost to Municipal; Commercial and Domestic Sectors, and Permanent Losses for the Industrial and Domestic Sectors.

The results of the losses which may be expected with the two assumed hydrologic runoff conditions are given in Table 13 for the project. A full description of the methodology for the evaluation is given in Appendix F.

Utilizing the information contained in Table 13, a benefit/cost analysis was made for the project. In developing the benefit/cost ratio shown, a discount rate of 5-7/8 percent and a 50-year project life was used. The losses were estimated on a year by year basis into the future.

TABLE 13

LOSSES PREVENTED BY IMPLEMENTATION OF NORTHFIELD MOUNTAIN [1] PROJECT

(1972 Dollars) Millions of Dollars

Year	Industrial	City Emergency	City Revenue	Commercial	Sprinkling	Business Investment	Domestic Investment	Total
				Normal (Average) Runoff Conditions				
1982 [2]	.326	.740	1.747	.165	.429	0	1.689	5.096
1990	.620	1.347	3.522	.333	.745	0	.423	6.990
2000	.950	1.911	5.475	.568	1.068	0	.384	10.355
2010	.235	.723	3.294	.275	.455	0	-.053	4.930
2020	.012	.499	3.059	.245	.359	0	.022	4.195
				Drought Runoff Conditions (Sixties Drought)				
1978 [2]	.570	1.362	2.824	.284	.800	0	6.064	11.905
1979	1.454	3.393	7.024	.721	1.994	0	30.832	45.420
1980	1.211	2.762	5.715	.598	1.626	0	.186	12.097
1990	.620	1.347	3.522	.333	.745	0	.103	6.670
2000	.395	.923	3.441	.282	.531	0	.099	5.474
2010	.235	.723	3.294	.275	.455	0	-.253	4.730
2020	.012	.499	3.059	.245	.359	0	-.335	3.838

(1) Based on a proportion of yield made available from this project and the Millers River Basin Alternatives. Tables in Appendix F. thus are modified by the ratio 72/120.

(2) Years shown are the dates when restrictions would be necessary based on criteria described in Appendix F.

The capital dollar losses were then brought back to year 0 using present worth single payment factors to get a capital dollar value at year 0. These capital dollar values were then amortized over the life of the project to put them into annual dollar values. The loss figures on an annual basis were then compared with the annual costs[1] of the alternative projects yielding the benefit/cost ratio. These ratios are shown in Table 14. As illustrated, the benefit/cost ratio varies from 1.2 1.9 for average rainfall - runoff conditions, with the assumed drought condition superimposed on the water supply system.

Based on this analysis, then, the project would provide an economically justified protection for the receiver communities.

TABLE 14

REGIONAL DEVELOPMENT OBJECTIVE

BENEFIT/COST RATIO[2]

NORTHFIELD MOUNTAIN DIVERSION PROJECT

Normal Runoff (Average)	Sixties Drought Runoff
1.2	1.9

As stated earlier, impacts on the receiver areas as the result of water shortages can be expressed two ways. The first, described in the previous sections, counts economic losses which could occur with water use restrictions. The categories included in those totals encompass industrial, city emergency, city revenue, commercial, sprinkling, business investment and domestic investment losses. However, the dollar losses shown do not illustrate how such losses might be allocated. For example, of the more than two million dollars in municipal revenues not collected in 1990 as a result of water shortage, there is no way of knowing whether it would be recreation or education budges that suffer.

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[1] Shown in Table 8.

[2] Based on a prorated by yield average of losses prevented by both Northfield Mountain and the Millers River Basin water supply projects.

In an attempt to allocate these economic losses, the impact categories described in Table 9 were utilized. Using these categories, Table 15 was constructed. As shown in Table 15, impact category 6 lists loss in classrooms not built as one possible expression of total dollar loss. Similarly, housing units not built are but an alternative manifestation of losses in the private sector. Therefore, to avoid double accounting, the impacts set out in categories 5 and 6 should not be summed with those in other categories.

Still, some quantification of these two important social impacts, as well as those in categories 1 and 7 - 15, was necessary, if only to provide order of magnitude estimates.

To provide the estimates for these categories, an examination was made of the experience of an actual community already beset by the kinds of problems anticipated in the event of prolonged water shortage. Principally, "soft data" related to social impacts were the objective. How does a community respond to the dislocations of water use restrictions? Do citizens get more involved in planning when crisis conditions are sustained over a long period? How quickly does population growth slow in response to water-use and building restrictions? An extended interview with Stoughton's Planning Board Chairman produced both background and impact information.

Stoughton is an industrial - residential community in the Brockton Standard Metropolitan Statistical Area. The town's population of about 25,000 is growing at a rate of more than 40% every decade, and shows no signs of a downward turn. The principal constraint on continuing growth may be an acute shortage of water. Presently, municipal supplies come from five town wells; two recently completed standpipes with capacities of 10 and 2 million gallons, respectively, give Stoughton about 14 million gallons of total storage. The severity of ongoing shortages are indicated by a complete ban on outside watering in effect for several years and a one-year freeze on the issuance of building permits which was lifted last year.

The town has been searching for water since 1955. First, an extensive drilling effort at producing well sites was tried. When the results were negative, consulting engineers were engaged to search for new groundwater sources; results, negative or unacceptable because of high iron content. Last year, a grant of $1.5 million funded a project to clean or replace defective distribution piping. In addition, $150,000 was spent on a connection with Brockton and Canton water supplies. This, however, is seen as only a temporary measure because these two towns can

terminate the arrangement at will, whenever their capacities are strained. In general, admission to the MDC system is viewed as the only permanent solution. Formal application has been made, but even favorable action means a delay of possibly 8 - 10 years before Quabbin - Wachusett water becomes available.

The consequences of water deprivation have been felt across a wide range of community activities. The following paragraphs, keyed to Table No. 15 discuss the impact of the 1960's drought and the continuing water shortage on the Town of Stoughton, Massachusetts.

/a/ Land Use

Although no shifts in the allocations of land use type have occurred, development in the industrial category has been nearly stopped by water shortage. Interestingly, though a building ban prevented "new starts" on residential housing for a year, the rush to develop after the ban was lifted has more than wiped out any deficit.

/b/ Population

While data projections for longer terms show population deficits for deviations from the "enough supply" situation, it does not appear that population growth is sensitive to short-term controls and constraints. Stoughton's in-migration continued despite the building ban and shows signs of growing even more quickly now that new housing construction has begun again.

/c/ Municipal Finance

Because finding water has been a top town priority, other municipal services have suffered. A sidewalk program has been indefinitely postponed and only minimal roadway maintenance and construction has occurred. Generally, expenditures have been cut as revenues from expected property taxation have dwindled. Estimates range as high as $1,000,000 in tax losses with increases in assessments covering the deficit. The cost of water has doubled in the past two years and the municipal debt as of January 1, 1970 stood at $7,516,000 or $320 per capita. Until a mutual help agreement was reached with Easton and Sharon, adequate fire protection was a critical concern.

/d/ Commercial Activity

In the time observed by the interviewee, there have been no perceptible consequences for either retail or wholesale trade.

TABLE 15

IMPACTS ON RECEIVERS
NORMAL RUNOFF CONDITIONS

Impact Category	Measures Applied to Receiver Area (66 elements)	Northfield	No Project
1. LAND USE /a/	Net change, % distribution, by use; industrial, commercial, agricultural, residential, recreational	No Change	No differential change; general retardation in industrial and residential growth
	Net use change, in acres, for land taken	N. A.	N. A.
	Net change in developable land, as % of land taken	N. A.	N. A.
2. POPULATION /b/	Net divergence from unconstrained baseline trend of:		
	2,893,100 in 1990;	2,893,100	2,769,600
	4,057,800 in 2020;	3,689,800	3,384,700
	Net change in age, race, ethnicity distribution	0	0
3. MUNICIPAL FINANCE /c/	Net change in revenue resulting from water service, 1990	$2,762,000 [1]	$3,870,000
	2020	$15,573,000	$18,762,000
	Emergency water expenditures, 1990	$1,056,000	$2,245,000
	2020	$4,980,000	$5,542,000
4. COMMERCIAL ACTIVITY /d/	Net change (losses) over normal trends; 1990	$261,000	$555,000
	2020	$2,044,000	$2,313,000
	Number of businesses displaced by facilities	N. A.	N. A.
5. HOUSING /e/ Stoughton	Net change in number of new housing units; upper limit	0	-3750 units per year
	(Average decrease 125 units per year)		

N. A. = not applicable U = data unobtainable for calculations at this level of detail

[1] All dollar figures are 1972 price level.

TABLE 15 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	Northfield	No Project
6. EDUCATION /f/	Net change in amount of classroom space required for projected change in school age population; order of magnitude estimate	0	30, twenty-room schools, or 600 rooms not built
	Net change in cost of teaching staff required for projected change in school population (average salary/year = $10,000)	0	900 staff, or $9 million not spent in salaries
	Net change in cost of providing school bus services because of changes in housing	0	U
	Use of facilities for educational programs; upper limit, days/year	20	0
7. LEISURE OPPORTUNITIES	Net change in total number of acres of parks and playgrounds	0	0
	Net change in extent to which planned recreation space meets American Society of Planning Officials standards	N. A.	N. A.
8. CULTURAL OPPORTUNITIES	Total number of churches, historical sites, or other cultural institutions taken	N. A.	N. A.
	Cost of relocation	N. A.	N. A.
	Increase in locational amenities; fountains, pools, etc.	20-30	0
9. TRANSPORTATION	Net change in travel time as a result of facilities construction	N. A.	N. A.
10. MUNICIPAL SERVICES (See /c/)	Net change in providing water, sewerage, garbage service or other municipal services	0	0
	Net change in residential insurance rates	0	0

TABLE 15 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	Northfield	No Project
11. SECURITY /g/	Number of positive and negative statements about the opportunity for system failure	10-20, principally related to radiological hazards of diverting waters downstream of Vernon, Vermont Yankee outfalls	Episodic concern for prolonged and widespread water shortage caused by Quabbin depletion
12. COMMUNITY IMAGE /h/	Changes in property values adjacent to supply facilities	N. A.	N. A.
	Number of positive and negative statements about communities as revealed by content analysis of local media (average 20/year/community); order of magnitude estimate	0	c. 600 Increasing negative comment as watering restrictions put into effect
	Sprinkling losses, 1990 2020	$584,000 $2,937,000	$1,242,000 $3,328,000
13. COMMUNITY COHESIVENESS /h/	Total number of community, regional, statewide and national groups taking a position for or against; average of 4 per community concerned; 3 in favor 1 opposed	90 in favor 30 opposed	100 in favor
14. CITIZEN INVOLVEMENT /h/	Total number of community, regional, statewide and national groups involved in planning of the project X		
	Level of involvement on the following scale: 2 x 60 x 3	360	360
	1. Attendance at hearing 2. Citizen opportunity to critique plans at public meetings 3. Periodic workshops planning sessions with community representatives 4. Community advocate planner participated on equal basis with technical staff 5. Appointment of an arbitrative hearing officer		

TABLE 15 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	Northfield	No Project
15. INSTITUTIONAL INVOLVEMENT	Total number of jurisdictions involved in the totality of the construction process for water supply facilities;	No primary sites, connections only; upper limit, 1990 15	N. A.
	Number of applications submitted to M. D. C. for water supply service, disposition and frequency of refusal; upper limit, 1990, 23 "no option" communities 5 actual petitioners (Bedford, Burlington, Reading, North Reading, Wilmington) 2 additional communities	30, increasing frequency of admission	30, decreasing frequency of admission
16. ECONOMIC STABILITY /1/	Net change in local economic activity; value added deviation from unconstrained supply level of $ 446,000,000 in 1990 $1,398,000,000 in 2020	$364,800,000 $903,400,000	$364,800,000 $903,400,000
	Net increase in private investment	0	0
17. REAL INCOME	Net change in per capita income		
	Net change in tax assessments per individual taxpayer		
	Net change in regional income; Total concrete losses, 1990 Total concrete losses, 2020	$5,481,000 $29,708,000	$11,650,000 $34,149,000
	Total domestic investment losses, 1990 2020	$331,000 $1,200,000	$705,000 $1,169,000

TABLE 15 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	Northfield	No Project
18. EMPLOYMENT	Number and type of jobs saved/lost	0	U Employment falls at about the same % as value added
19. INDUSTRIAL ACTIVITY	Change in number of industrial establishments	0	U
	Change in productivity		Declines as revealed by declines in value added
	Total industrial investment losses, 1990	$487,000	$1,034,000
	2020	$2,974,000	$3,036,000
20. AGRICULTURAL ACTIVITY	Change in number of farm acres, upper limit	N. A.	N. A.
	Change in production per acre	Water used for agricultural purposes is not drawn from public supplies.	

/e/ Housing

Since the lifting of the building ban, over 500 rental units have been built and occupied. The demand for housing has lowered the vacancy rates significantly and stimulated the construction of 3,000 apartment units and the planned development of 3,000 more. Before the ban went into effect, issuances of building permits had declined an average of about 130 units per year for two successive years.

/f/ Education

Two primary schools of twenty-six classrooms each have been completed in the past two years (September 1970 and 1971) to accomodate a swelling elementary-age school population. A much-needed junior high has been put off -- an effect attributed to the "extraordinarily high expenditures of finding water." As a result, the present junior high is expected to go into double sessions this coming fall.

/g/ Security

As the search for water has become "business as usual," citizens appear to have developed some tolerances for the inconvenience of watering bans. However, their latent insecurity about adequate supplies for fire protection and general domestic consumption have made water shortage a perennial political issue on which concern can focus. As noted above, the prevailing attitude is that "everything will be all right" once MDC admission is secured and the burden of water planning can be shifted to the Commission.

/h/ Community Image

Despite the general slowdown in industrial development and its second order consequences on town revenues, the average citizen perceives the water supply problem in terms of his own inability to water outdoors. Lawns and shrubbery are a waste of money, says the homeowner, and the town looks poorer for it. A general feeling of discouragement and frustration has set in and the desireability of Stoughton as a residential community has been adversely affected. So far no monetary reflections of this malaise have developed and property values are as yet unchanged by water shortage.

/i/ Economic Stability

Economic development has been hurt because water using industries have been turned away. This has "slightly decreased" the stability of the town

because the tax base has not expanded quickly enough to keep up with demands on local revenues. Wages and prices have remained in phase with the rest of the state, but taxes have increased.

/j/ Industrial Activity

No Stoughton industries have left because of water shortage, but new industries (chemical plant, refinery) have gone elsewhere. Presently, only non-manufacturing, non-processing firms are permitted to locate in town, and a $40 million industrial park is now two years behind in its development schedule.

Using data collected in the Stoughton case study, adjustments were made to reflect forecasts of impacts on the receiver area. In every case, values were multiplied by a factor of thirty: twenty-four "no option" communities for whom prolonged water shortages could be expecially severe and six others, roughly one out of every three now "partially-served" or served non-members. Since the impact estimates produced in this manner are undoubtedly high, no separate account was taken of communities already fully served. That is, for example, the thirty, twenty-room schools not built because of slowed population growth in the "no go" situation represent a system maximum whether or not it is precisely the "no option" or "partially served" communities which fail to erect them.

One further note should be made regarding Table 15. The data shown with the exception of the values presented for the seven loss categories described earlier were not adjusted for the yield [1] of the project. Since the other data is qualitative, it was felt adjustments to further refine the information was not warranted. In addition, the With Diversion Project column reflects a satisfied condition, that is, water demands are met. To meet water demands, however, another supply project would be needed. That other project, the Millers River Basin development, is the subject of a separate, but companion report.

Social impacts, then, in the receiver area are principally "shadow costs" of losses generated by water shortage. As municipal efforts turn to finding new sources, building bans to hold the line on new demand are a likely eventuality. Second-order effects of expenditures on water searching manifest themselves as slowed school building programs, poorer municipal services (especially fire protection) and a general malaise in the development plans of the subject towns. Moreover, it appears that citizens are likely to become discouraged and frustrated as they see their lawns dry up during watering bans. In many ways, these

[1] In the analysis conducted the Northfield Mountain and Millers River Basin development were evaluated for their aggregate impact on receiver communities. See Appendix F.

feelings are reflected in attitudes about the desirability of their town as a place to live and work. The net result is stagnating growth, hostility toward the communities which snare the industries unable to locate in a water-deprived town, and a growing dependence on MDC admission as the ultimate solution to water shortage.

Short-term, project-specific impacts on receiver areas are seen as virtually non-existent. Remembering that no actual water deliveries from the Connecticut Basin would be made short of five years from the start of construction, economic impacts perceived in the MDC service area would not be water-related. For example, it might be that certain portions of the supervisory and office labor force required for construction might come from cities and towns incidentally served by the MDC. Or, it is possible that equipment required for construction or permanent installation may bring revenues to a jurisdiction classified as a receiver. However, such stimuli are likely to be very small indeed because the dichotomy between supplier and receiver areas is nearly perfect.

Long-term impacts -- those generated by the availability of that yield increment provided by the diversions -- are more tangible. In a general sense, receiver areas will continue to develop along the optimistic lines suggested by their respective Master Plans.[1] Therefore, interruption of service is not expected to occur and industry, especially, can be free of nagging doubts about the risks of water use restrictions. Developers of residential housing slated for existing MDC service communities and those expected to join before 1990 are not likely to take their investments elsewhere as a result of threatened water shortages.

With respect to the water supplied itself, receiver communities benefit from implementation of the diversions in two specific ways. First, exceptionally high water quality will not change. Households and industrial establishments accustomed to minimally treated upland water supplies will not be required to tolerate or compensate for waters of lower quality until such time as even the Connecticut diversions become inadequate to meet demand. This will be particularly important to manufacturers using large amounts of water for purposes other than cooling and those to whom deferred investments in treatment and recycling are desirable. Likewise, homeowners will not have to search for other sources of supply and sustain the cost of sprinkling losses. Moreover, it is unlikely that MDC members will be subjected to the large price hikes that may be associated with the restrictions imposed earlier under a no-go condition.

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[1] These documents uniformly assume unconstrained water supplies in their development of growth expectations.

B. National Economic Development Account

The National Economic Development (NED) objective is enhanced by increasing the value of the nation's output of goods and services and improving national economic efficiency. Components of the NED objective include:

a) The value to users of increased outputs of goods and services resulting from a plan. For example, the projects reported upon in this study would reduce descriptions of economic activity due to water supply shortages, thus leading to direct increases in productivity from water and land development that contribute to national output.

b) The value of output resulting from external economics. In addition to the value of goods and services derived by users of outputs of a plan, there may be external gains to other individuals or groups. For example, the projects included in this study would maintain a viable economy in receiver communities. Such maintenance of a strong economy in the northeast would then benefit the nation as a whole.

In the assessment of the Northfield Mountain project's impact on the NED account, much reliance was placed on the economic loss categories described earlier. This is not to say that some of all of the social impacts described in the section on Regional Development do not carry into the NED account. The reader should be cautioned, however, that the economic losses described in the following paragraphs are not all inclusive of losses which may be sustained without the availability of additional supply.

In evaluating the economic losses prevented by implementation of any of the alternative projects, seven loss categories were examined. These are: Annual Losses to the: industrial, municipal-emergency, municipal-lost revenue, commercial and domestic sectors; Permanent losses to industrial and domestic sectors.

Upon examining the losses in each category, it was decided that losses in four of the categories, municipal-emergency, municipal-lost revenue, domestic annual losses and investment, represented losses to the nation as a whole. These four categories, therefore, were carried fully from the Regional Development account into this account.

The remaining three loss categories investigated, industrial business losses, commercial losses and industrial investment losses, were felt

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to more represent regional rather than national losses. That is, elements in these three categories which suffered losses in the region could be replaced by increased business activity in other parts of the nation.

Based on the four loss categories considered affecting the NED objective, a benefit/cost ratio for the project was constructed and is presented in Table 16.

As illustrated, the benefit/cost ratio for the project varies under normal (or average) hydrologic runoff conditions from 1.1 to 1.7 simulated sixties drought conditions.

Based solely on economic losses, then, construction of the project would prevent more losses to the national economic development objective than the costs of implementing the project. In addition, as stated earlier, these economic benefit/cost ratios do not reflect the social impacts to the nation which might be occassioned by water shortages. If these social impacts, described under the Regional Development account, are also considered as affecting the nation as a whole, then the effects of water shortage on the National Economic Development account are multiplied.

TABLE 16

NATIONAL ECONOMIC DEVELOPMENT OBJECTIVE

BENEFIT/COST RATIO [1]

NORTHFIELD MOUNTAIN DIVERSION PROJECT

Normal Runoff (Average)	Sixties Drought Runoff
1.1	1.7

C. Environmental Quality Account

1) General

From the outset of this report, efforts have been made to determine the impact of the Northfield Mountain water supply diversion element on the environment. An evaluation was made of the project's impact on the Connecticut River estuary, on the Connecticut River downstream from the point of diversion and on the environment of the receiving water storage reservoir, i.e., Quabbin.

[1] Based on a pro-rated by yield average of losses prevented by both Northfield Mountain and the Millers River Basin water supply projects.

To conduct these investigations, both in-house capability of the New England Division's Environmental Resources Section, as well as contractor personnel, were utilized. The following sections describe in summary the efforts of this integrated multi-discipline team of both Corps of Engineer personnel and services from two environmental consulting firms. More detailed descriptions of the studies are given in Appendices E and F.

2) Possible Environmental Impacts of Diversion on the Connecticut River Estuary

In evaluating the possible environmental impacts which might occur within the Connecticut River estuary, contractor services were utilized extensively. Recognizing that this project's proposed diversion rates are small in comparison to the total river flow and that other proposals for diversion were also being considered in the Millers River Basin, it was decided to test effects[1] which might occur with a large range of postulated diversion rates.

The range of postulated diversion rates tested varied from 600 cfs to 4000 cfs with adherence to a minimum control flow at Montague City of 17,000 cfs and 12,000 cfs, as measured at the U. S. Geological Survey gaging station. Only the 17,000 cfs control flow rate has been approved by the Massachusetts Legislature.

The use of the large range of postulated diversion rates, i.e., 600 to 4000 cfs, with corresponding control flow rates of 17,000 and 12,000 cfs, thus were adopted to allow a full investigation of any potential impacts on the estuary. For example, if the larger postulated diversion rates were tested and limited impact predicted, then the lower diversion rates could be expected to exhibit even less of an impact. This, in fact, is what the results of the study concluded as summarized in the following paragraphs. A complete description of the study is given in Appendix E.

a) Changes in river temperature due to diversion should not exceed 0.61° F under the worst case postulated (i.e. 12,000 cfs at Montague City and 4,000 cfs diversion). Although many biological effects of temperature elevations are well known, in most cases the effects resulting from such a small temperature increment are too small to quantify.

Biological evaluations were made using a 2° F temperature rise in the estuary. The rationale for choosing this temperature rise is twofold. First, biological changes could not be predicted on much less than a

[1] Possible Effects of Various Diversions From the Connecticut River Estuary. Essex Marine Laboratory, Inc., May 1972. Prepared for the New England Division, Corps of Engineers.

2° F increment of change, and secondly, it would be only an academic exercise to try to refine predictions at a smaller increment of change if, in fact, no significant changes would occur at the 2° F increment. As it turns out, even a 2° F temperature rise would not cause a serious impediment to diversion plans as far as the ecological balance of the estuary is concerned. Keeping in mind that the calculated temperature rise is less than 1/3 the value used in biological evaluation (.61° F vs. 2° F), the reader is advised of the apparent conservative nature of the biological evaluation that is summarized in the following paragraphs.

Among the known biological effects of increased temperature, the following may be expected, but it should be kept in mind that even if deleterious, the small change in temperature will result in too small a magnitude of change to be cause for alarm.

All of the conclusions regarding temperature and biological change are based on the worst condition tested, i.e., 4000 cfs diversion with 12,000 cfs at Montague City.

(1) Change in the Time and Location of Shad Spawning - Calculations indicate that a 2° F temperature rise in the river water would have caused spawning to occur 3.4 days earlier in 1967 and 3.6 days earlier in 1968. It is postulated that the most severe postulated diversion conditions would have an insignificant effect on shad spawning.

(2) Shad Egg Size, Abundance, Development Time and Mortality - Shad spawning success in general will not be greatly influenced by any of the postulated diversion. After diversion, temperatures would still remain well within normally occurring variations; and since spawning occurs well above salinity intrusion, any changes in salinity patterns will not affect spawning.

(3) Effects of Survival of Larvae of Shad and Resident Fish Species - Temperature rise and salinity changes that would be brought about by postulated diversion are not expected to affect the egg or larval survival development or growth of any of the fish species tested.

(4) Adult Fish Populations - Some adult fish could feel an effect of the diversion as a result of shifting (in time) of the availability of a food supply. Food generally becomes available as temperatures exceed 40° F. A 2° F temperature rise would have caused this 40° F temperature to be reached 4.3 and 6.8 days earlier in 1969 and 1970, respectively. Since some adult fish winter in coves and do not move out into the river until temperatures reach 40° F in the coves, they may

arrive in the river up to a week after the food supply begins to develop. This assumes that water temperature in the coves would not be influenced by the 2° F temperature rise in the river. More information is needed in this area to draw any definite conclusions, but no problem of significant proportions is anticipated.

(5) Homing Ability and Timing of Arrival of Adult Shad - Adult shad appear to have no homing problems even during extreme low flow springs. Diversion will not reduce flows during these extreme low flow conditions so that it is logical to assume that the shad's homing will not be impaired by diversion. Historically, it has been found that shad tend to enter the estuary when temperatures reach 40° to 43° F. Diversion would cause these temperatures to be reached somewhat earlier, but no problem is anticipated.

(6) Microbiological Population - Because of the paucity of data in some critical areas of basic biology, deemed pertinent considering the postulated diversion, no absolute predictions can be made regarding the ultimate fate of microorganisms in the estuary. Since temperature and salinity rise are so small (2° F and a few mg/l) at any given point and since these changes develop over a period of time, no significant qualitative or quantitative alterations of bacterial populations are to be expected in the short run (a few years). Beyond this span any prediction would be speculative.

(7) Invertebrates - 48 recurring species of invertebrates have been identified in 60 months of sampling. Of these, four species are dominant. A 2° F temperature increase can be expected to increase the metabolic activity and probably advance sexual maturity slightly in each of the above species. However, since considered diversions will not be made during summer low flow, high temperature situations, these species are not put under any undue stress. Temperatures after diversion will still be well within the limits of naturally occurring variation, and only minimal adverse effects are to be expected.

b) Freshet conditions should continue throughout the estuary if no diversion takes place when flows are less than 17,000 cfs at Montague City. The duration of freshet will be shortened by 2 to 4 days at both the onset and cessation of freshet in a normal year with diversion. If 12,000 cfs were considered as a control flow, then freshet conditions would be shortened by 3 to 9 days at both the onset and cessation of freshet in a normal year.

c) At a 12,000 cfs controlling flow at Montague City, minor reversals of current may occur in the lower estuary. These should not be sufficient to cause a biologically significant intrusion of salt water from Long Island Sound.

d) Under either controlling flow regime, changes in salinity distribution would be too small to have measurable biological effects.

3) Possible Environmental Impacts of Diversion on the Connecticut River

a) General

The Connecticut River itself is the largest river basin within New England. The river drains an area of 11,265 square miles of which about 7,200 square miles are located upstream of the proposed diversion intake.

Downstream from the intake, the river flows south for about 63 miles prior to the tidal portion of the basin. In this downstream reach, the river flows through rural as well as highly populated centers such as Springfield, Chicopee, and Holyoke, Massachusetts, and Hartford, Connecticut.

Historically, the Connecticut River has supported major runs of anadromous fishes, including American shad, alewives, blueback herring, rainbow smelt, sturgeon, and Atlantic salmon. Though the first four of these species still complete their annual migrations for spawning within the lower reach, all were eliminated from the upper portion subsequent to dam construction. The Atlantic salmon has been entirely eliminated. A sport fishery does exist throughout the river's length; however, it reaches peak importance along the tributaries, which receive annual stockings of trout to maintain a "put-and-take" sport fishery. Present efforts are being expended to restore anadromous fish to the entire watershed through construction of fish passage facilities at obstructions not having these structures and through re-introduction of salmon. Pollution abatement within the entire watershed is expected to lead to restoration of high quality aquatic resources and their utilization.

Within the vicinity of the diversion intake, anadromous fish species are not now found; however, approximately 25 resident species have been collected within this reach. Three of these species are important sport fishes (yellow perch, bullhead and small-mouth bass).

As described earlier, the diversion for water supply purposes would withdraw about 580 cfs from the river and this flow would then be

conveyed to Quabbin Reservoir. Diversions would only be made contingent on a minimum control flow of 17,000 cfs as measured at the U. S. Geological Survey gaging station at Montague.

Based on long-term stream flow records maintained at the Montague City gage, the amount of water to be withdrawn would be about 1% of the average annual run-off from the river. A plot of the proposed withdrawal effect on the long-term average monthly hydrograph is shown on Plate No. 12. In addition, the maximum decrease in river stage caused by the diversion would be about 0.2 feet at Montague City or about .05 feet at the Thompsonville, Connecticut gage.

b) Change in Concentrations of Nutrients

Based on data developed by the University of Massachusetts as part of a research grant, ammonia-nitrogen loads in the Connecticut River at Northfield for 1963 - 1965 were 3,800 pounds per day. Downstream at Thompsonville, Connecticut, loads for the same period were recorded as 35,900 pounds per day. Phosphate-phosphorous at Northfield for 1963 - 1965 was estimated to be 6,700 pounds per day, while at Thompsonville, about 33,000 pounds per day were recorded.

The diversion from the Northfield Mountain would little affect nutrient levels downstream from the diversion. Maximum differences in concentration at Thompsonville for ammonia-nitrogen and phosphate-phosphorous would be less than .01 ppm.

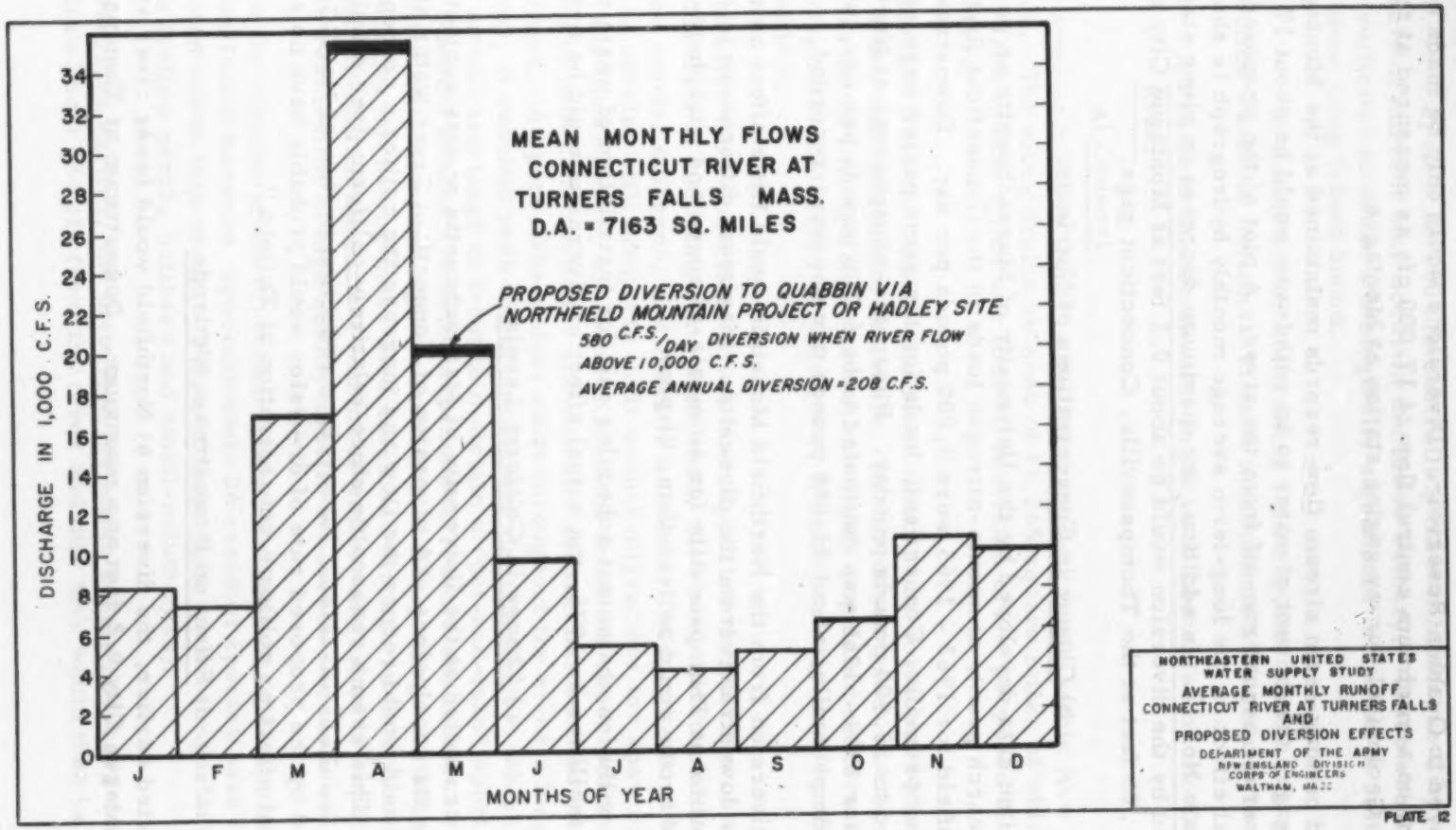
Since pollution abatement schedules call for installation of waste treatment facilities by 1976, the actual effect of diversion would be even less.

c) Change in Coliform Levels

Work conducted at the University of Massachusetts on this subject had among its conclusions, "A diversion of Connecticut River water at Northfield would reduce the flow and increase the coliform concentration. This seems reasonable since relatively coliform-free dilution water would be diverted. However, a reduction in flow at Northfield caused by the proposed rate of diversion would probably have no significant effect on coliform concentration at Enfield."

d) Effect on Downstream Wetlands

As stated earlier, the diversion at Northfield would lower river stages at Montague City 0.2 feet at a maximum. Downstream at Thompsonville,


MEAN MONTHLY FLOWS
CONNECTICUT RIVER AT
TURNERS FALLS MASS.
D.A. = 7163 SQ. MILES
PROPOSED DIVERSION TO QUABBIN VIA
NORTHFIELD MOUNTAIN PROJECT OR HADLEY SITE
580 C.F.S./DAY DIVERSION WHEN RIVER FLOW
ABOVE 10,000 C.F.S.
AVERAGE ANNUAL DIVERSION = 208 C.F.S.
DISCHARGE IN 1,000 C.F.S.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
J
F
M
A
M
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S
O
N
D
MONTHS OF YEAR
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
AVERAGE MONTHLY RUNOFF
CONNECTICUT RIVER AT TURNERS FALLS
AND
PROPOSED DIVERSION EFFECTS
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 12

the stage reduction would be .05 feet. Minimal impacts to downstream wetlands are foreseen for these limited river stage reductions.

e) Effect on Planned Water Quality Improvements

Implementation schedules for waste treatment facilities on point sources of pollution have been established by the Environmental Protection Agency and the basin states. All plans for pollution abatement are based on meeting adopted water quality standards during low flow conditions. Since diversions considered in this project would only occur during high flow periods when flow is 17,000 cfs or greater at Montague City, no impact would occur to impair planned water quality goals.

f) Effect on Water Temperature

Studies conducted within the estuarine portion of the basin indicated a maximum of 0.06° F rise could be expected in the estuary following diversion of 600 cfs. Upstream in the mainstem of the Connecticut River, the maximum change in temperature which would be caused by the diversion and subsequent loss of dilution flow would be about 3%. No significant effect on water temperature is anticipated, therefore, from the diversion.

g) Change in Level of Groundwater Table

A meeting was held with the U. S. Geological Survey to determine the impact which the diversion may have on groundwater levels. In the opinion of the Geological Survey, no significant impact to groundwater levels is anticipated as a result of the diversion.

h) Effect of Diversion in Flood Flow Bottom Deposit Scouring

Based on studies by the University of Massachusetts, it was estimated sediment load transport efficiency of the Connecticut River just downstream from the diversion intake would be reduced approximately 3 percent. Downstream from the intake, flow from intervening drainage area would cause the reduction in efficiency to be even less.

i) Effect on Aquatic Life in Vicinity of Diversion Intake

Diversion of water from the Connecticut River to the Northfield Mountain upper reservoir may affect the aquatic life in the vicinity of the river intake. Fishes, phytoplankton and invertebrate organisms of all

life stages may be entrained and/or trapped at the pumping facility. This impact is not occasioned by the fact of the water supply diversion, but rather by the operation of the Northfield project for power production.

j) Effect on Downstream Navigation

Below Hartford, Connecticut, the river is used for both commercial shipping and recreational boating. Upstream from Hartford to Holyoke, the river is used for recreational boating, but sand bars and shallow water during low flow greatly impede navigational use.

Normal navigation season flow at Hartford is considered to be 3,750 cfs, while the upper limit is considered to be 66,000 cfs.

The diversion would not affect low flow navigation conditions. High flow conditions would be affected, but not in a negative manner. Instead, the reduction in flow from the diversion would be a minor benefit due to slightly lower velocities.

k) Effect on Flood Control

The Corps of Engineers is presently working with electric utility officials on an operational schedule of the Northfield Mountain project during flood periods. At present, a draft report presenting methods of operation is under review. It is anticipated that operation of the facility would not have a detrimental effect on flood control measures within the basin.

4) Possible Environmental Impacts of Diversion on Quabbin Reservoir

This study generated and evaluated extensive data on the Quabbin and Wachusett Reservoirs and the Connecticut and Millers Rivers systems, with the objective of making predictions on the impacts of diverting portions of these riverine systems into Quabbin Reservoir. Field and laboratory data included approximately 100 parameters, including chemical, physical, biological, and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information, and pollution abatement plans were considered and evaluated. Finally, other pertinent data available from both public and private sources, especially on the Connecticut River, were evaluated in the light of the objectives of this study. A summary of this evaluation is given in the following sections. A complete description of the study results is given in Appendix D.

Central to the evaluation was the development of a qualitative model of reservoir dynamics. If water of lower quality is introduced from a

river system into a receiver system, there will most likely be a loss in water quality in the receiver system. This loss of water quality is due to various materials in the water. These materials include molecules, ions, suspended inorganic materials, organic debris, and living organisms. One of the central problems of ecology today is to trace the flow of materials from the various compartments of an ecosystem.

a) Possible Impact on Water Quality

In this section, changes in water quality as a result of the proposed diversion are evaluated. The discussion is limited to the more important issues; no attempt is made to discuss all parameters. Subsequent sections will deal with broader ecological issues, and will include most of the biological parameters.

Diversion of Connecticut River water into Quabbin Reservoir in 1976 will initially increase the turbidity of the reservoir water. The final turbidity will depend upon (1) fallout of some material, (2) the relative dilution of Connecticut River water by ambient Quabbin volume, (3) transformations of materials, (4) the influence of ionic strength changes, and the influence of pH changes. Based on only preliminary data, the fallout of material could be significant after a residence time of 60 - 90 days. The dilution, however, can never exceed a factor of about 5 to 10, depending upon what volumes and how much mixing one considers. Also, water originating in the Connecticut River will be between 18 and 19% of the volume of the entire reservoir, depending on the availability of other diversions during the period 1980 to about 2000. Transformations may change the molecules or colloidal aggregates, but will not necessarily cause an elimination. Finally, the Connecticut River water will undergo a drop in specific conductance after it enters Quabbin; this will tend to stabilize the colloidal suspensions. If it is assumed that the Connecticut River will have an average turbidity of less than 25 during freshet flow, and that extremely high values are possible but infrequent occurrences, all factors considered above will tend to bring the final turbidity down to a lower value. While it cannot be predicted what this value will be, it will probably vary between 0.5 (present turbidity) and about 2. Thus, it may not meet future U. S. Public Health Service (1 JTU) standards for drinking water. The turbidity will probably not rise as much during the first two diversion cycles (years 1976 - 1978) because of the smaller relative proportion of total water originating in the Connecticut River.

Ions that form insoluble complexes (Mn, Fe, Ca) tend to precipitate out into the sediment if suitable anions are available. Such anions decrease

as the pH becomes more acid, and thus these ions will tend not to precipitate out as the Connecticut River waters mix with Quabbin waters. Depending on the quality of other waters introduced to the reservoir in the future, there may be a tendency to balance. However, it cannot be predicted what the trend will be over a two-decade period, because the exact proportions cannot be predicted and the long-range stability for pH values in all systems is unknown.

There are at least two major concerns on the possible deterioration of water quality that have ecological significance. One concerns oxygen depletion, and the other is the introduction of additional nutrients which can lead to eutrophication.

Available data suggests that Chemical Oxygen Demand (COD) values for the Connecticut River are about twice as high as the Quabbin stations. Both Connecticut River and Quabbin Reservoir waters maintain high 0_2 levels, and during the freshet flow periods are probably close to saturation. The concern here is an assessment of the potential depletion of 0_2 from Quabbin waters as a result of the proposed diversion.

COD represents a potential 0_2 consumption that is measured using a strong chemical oxidizing agent. Depending on the ease with which the material can be oxidized under natural conditions, the full COD may or may not be exerted upon the water.

If most of the COD is in particulate form (which is probably true for the Connecticut River) much of the material with a potential demand for oxygen could settle out either in the Northfield Pumped Storage Reservoir or in upper Quabbin Reservoir after diversion. Although settling reduces the COD of the water column, the potential oxygen demand is conserved in the mud. Moreover, the organic component of the sediment may be acted upon at the mud-water interface, and transformed into more easily oxidized compounds. Some materials in the diverted waters may interfere with biological activity in the mud-water interface and either inhibit or enhance the transformation processes. Seasonal turnover and wind effects can stir up these bottom deposits into the water column. These effects are intensified if the reservoir levels decrease. The resuspension of transformed organic muds can serve to deplete available oxygen quickly because COD that had accumulated over many years through the settling process is suddenly present in the water column. If the stirring of the bottom mud never occurs, then COD that is settled out may be buried in the anerobic sector of the mud and may never exert its 0_2 demand on the water.

Included in COD values are the oxygen demands of inorganic materials such as iron and manganese. These inorganic species can have high 0_2 demands if they are in a chemically reduced state. However, in the Connecticut River, laboratory analysis shows that the iron is mainly Fe III and that the manganese may also be already oxidized.

All the above factors make it difficult to predict the impact of diverting Connecticut River waters with a higher COD into Quabbin Reservoir. Localized oxygen-depletion effects have been observed in the eastern arm of the reservoir. It is probable that similar effects will be observed after diversion in the northern part of the reservoir as well. The impact on the hypolimnion in the deeper part of the reservoir cannot be predicted at this time. Oxygen depletion will depend on a complex of biological and chemical processes in these aquatic systems. In conclusion, then, it is very possible that the proposed diversions may result in some localized oxygen depletions in the reservoir. The extent and magnitudes of such depletions cannot be predicted. As described earlier in the section on "Water Treatment Required" the impact on Quabbin must be carefully observed and monitored. If necessary, the option of diverting flow to more than one location within the reservoir can be exercised by extension of the tunnel stub described earlier.

A number of mechanisms can be expected to operate after the diversions of river waters. Much of the larger material will settle out, probably within hours and days. Many transformations can be expected, based on both inorganic and biological reactions. Detergents would be degraded, although no significant MBAS[1] levels were found. As the carbonates from the Connecticut River reach the more acid reservoir waters, equilibria will shift and some CO_2 will go off to the atmosphere. Organic materials including the CCE will probably be oxidized. Some NH_3 may also be oxidized, but most of it would be transformed by the biota. Color would decrease. This loss of color could be at least tenfold, based on evidence from the existing Ware River diversion. Finally, many highly insoluble organic materials, including hydrocarbon pesticides and organomercury compounds would tend to evaporate, as they reach the relatively large surface area of the reservoir.

The general trend will be towards an improvement in quality as the diverted water is retained in the reservoir. Whether the retention time within the reservoir before the Connecticut River water reaches the general position near the reservoir main water supply outlets is sufficient to cause recovery is unknown. However, the much longer

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[1] MBAS - Methylene blue active substances, found in most household detergents.

retention times to reach the Chicopee Valley water supply outlet could also allow for some recovery. It cannot be predicted that dilution with ambient reservoir volume will not restore the water quality alone. Some "fallout" of materials due to sedimentation, transformation and evaporation must occur to restore quality. The "treatment plant" capacity of the reservoir can probably handle some restoration of water quality. The magnitude of this capacity is now unknown. Because of its capacity to handle waters from the Ware River diversion with efficiency for 30 years of diversion, we may assume it has some reserve capacity. However, assuming that a loss of water quality occurs with some diversions of Connecticut River water, further deterioration will be checked if other sources of supply are added to the reservoir.

In summary, then, during the period prior to the Northfield Mountain diversion, the water quality will deteriorate as the volume in Quabbin Reservoir decreases. This loss of quality could progress to a dangerous point if the volume of hypolimnion waters is drastically reduced. Any losses in quality due to Connecticut River diversion must be judged in the light of water quality loss without diversion. Secondly, the volumes of water represented by Connecticut River origin will be relatively low during the first few diversions. This allows ample time to study the actual impact of diversion during a period of lower potential to cause a negative impact on water quality. Thirdly, future additions of water to Quabbin from other sources should improve the "treatment plant" capacity of the reservoir and thus an improvement in quality may take place. Also, it must be remembered that as the pollution abatement plans are implemented in the 1970's, the quality of riverine waters will improve. Finally, without even further sources of water inflow, Quabbin Reservoir is destined to deteriorate rapidly by the end of the century.

b) Possible Impact on Ecology

There can be little doubt that increased levels of nutrient chemicals will be detected in Quabbin Reservoir after the implementation of the Connecticut River diversion. However, not all nutrients can be expected to show such an increase in this time period. Phosphorus increases are possible, but not probable. Increases in available carbon, on the other hand, are quite probable if only due to the relatively high alkalinity of the Connecticut River. Also, the fact that fecal contamination of the Connecticut River does occur, increases the likelihood that complex organic molecules will be introduced into Quabbin and possibly into Wachusett where they will become part of the nutrient pool. The

future abatement of pollution in the Connecticut River will contribute significantly to the lowering of any such nutrient addition to the reservoir through diversion.

It is important to note that current nitrogen, phosphorus, and carbon levels in Quabbin are sufficient to support larger phytoplanktonic populations than presently exist. Increased levels of these nutrients do not necessarily mean, then, that higher concentrations of algae in Quabbin can be expected as a direct result of the diversion. It is quite possible, however, since nitrogen, phosphorus and carbon appear not now to be limiting, that the Connecticut River diversion may increase the levels in Quabbin Reservoir of some now unknown limiting growth factor, such as a vitamin. Additional studies on limiting growth factors in both Quabbin Reservoir and Connecticut River water is now under way by the MDC.

There is no reason to believe that undesirable algal species will be introduced into Quabbin Reservoir by either diversion. Any changes in the current algal populations in Quabbin will most likely be the result of the response of present populations in Quabbin to changing levels and kinds of nutrients brought about by the diversions.

The proposed diversion of Connecticut River waters into Quabbin Reservoir presents a good possibility of having an impact upon the maintained fisheries of Quabbin. Furthermore, in view of the fisheries management objectives of the Massachusetts Division of Fisheries and Game, the impact would be a negative impact. If it is assumed that undesirable species will be introduced into Quabbin Reservoir, then the consequences could be felt in several ways. First, the present managed ecological balance between species will be lost. Secondly, if the salmonid population is decimated by undesirable species competition, and a warm water fish population predominates, there is good likelihood that the number of angler trips by sports fishermen to Quabbin Reservoir will decline. This, in turn, will reduce the harvest and further influence ecological balance. The issue, then, is not a reduction of the standing crop of total fishes in Quabbin Reservoir, but the disruption of the present success in the management of a salmonid fisheries program. Studies on methods of excluding undesirable species and hence the consequences associated with their introduction are now being discussed by the MDC and the Massachusetts Division of Fish and Game.

Increased concentrations of organic molecules in Quabbin as a result of the Connecticut River system diversion may affect the dissolved oxygen content of Quabbin waters due to the oxygen demand of these molecules as discussed earlier. The magnitude of any overall decrease

in oxygen in the hypolimnion of Quabbin Reservoir, however, is not expected to cause significant changes in the present ecology of Quabbin Reservoir. Localized depletions of oxygen in Quabbin Reservoir have been periodically noted over the past half dozen years as a result of the present Ware River diversion. These depletions have been observed only in the southern part of the eastern arm of Quabbin, and have been short lived. The proposed diversions may be expected to produce similar, localized phenomena. The salmonid fisheries in Quabbin are not expected to be affected by any lowering of dissolved oxygen which is localized in the upper portion of the middle arm and in the eastern arm because they are typically found in the main body of Quabbin.

Because of the number of factors governing the disposition of pesticides in surface waters, it is not surprising that only small traces of pesticides were detected in this study. Similar findings are seen in the STORET retrieval data on the Connecticut River. Analyses for aldrin, BHC, DDT, dieldrin, endrin and other pesticides during the 1960's show little or no residues in the water. Finally, the findings of Lichtenberg et al. (1970) in a 5-year summary of pesticides in surface waters of the United States report only trace amounts (0.1 ppb) of pesticides in the Connecticut River.

A prediction with some certainty can be made about the ecological effects of pesticides in the proposed diversions. The Massachusetts Division of Fisheries and Game has data that indicate significant levels of DDT, endrin, dieldrin and PCBs in the tissues of lake trout taken from Quabbin Reservoir. These pesticides in lake trout reflect the expected concentrations by the food chain if traces of pesticides are already available in the reservoir ecosystem. Nor were the residues of DDT in fish from the Connecticut River (Lyman et al., 1968) any higher than those reported for the fish in Quabbin Reservoir. While more extensive monitoring of the waters, muds, and biota of both the Connecticut River and Quabbin Reservoir for pesticides would increase the certainty of prediction, it is highly improbable that the proposed diversion will have any important environmental effects.

Similarly, the impacts of the proposed diversions into Quabbin or Wachusett Reservoirs are impossible to discuss in detail until such a time as the specific impacts discussed above can be more fully defined by future studies. On the basis of current data, the possibility of a degeneration in turbidity in Wachusett deserves some mention due to the importance of turbidity in any contemplated future treatment of

Wachusett waters prior to their final distribution to consumers. Further studies sponsored by the MDC are presently under way on possible impacts in both Quabbin and Wachusett Reservoirs.

A summary of impacts on Quabbin Reservoir, which may be brought about by the proposed diversion via Northfield Mountain, is shown in Table 17.

5) Possible Environmental Impacts Caused by Added Waste Load of Reservoirs

In keeping with the objectives of the Environmental Quality account, the impact which added waste loads, occassioned by the additional water supply, from the project was also investigated. To provide a measure of the added waste load impact, it was assumed that the environmental cost would be considered as the cost of bringing the quality of water back to its original state. Estimates of providing advanced waste treatment to the incremental water supplied was made. It was assumed 70% of this additional supply would be treated; the remaining 30% would be lost from the system through evaporation, irrigation and consumed process water. The estimated costs of providing the necessary treatment is 3.4 million dollars on an average annual basis.

Care should be exercised by the reader, however, in translating this treatment cost dollar total to the earlier Regional Development and National Economic Development Accounts analysis. Offsetting the costs in general of this additional treatment required is the revenue lost to the MDC system if additional supply is not made available. For example, at present, water rates ($120/mg) revenue lost (or not available) without additional supplies totals 3.2 million dollars on an average annual basis. Using the anticipated new rate ($160/mg) revenues not available would total about 4.2 million dollars on an average annual basis.

In an attempt to preclude confusion by the reader in the Regional Development or the National Economic Development Accounts, neither the added waste treatment costs nor the benefit derived by the system in selling the added water were included. Thus, the two earlier account assessments are in essence addressed to an examination of net costs and net benefits.

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TABLE 17

SUMMARY OF PROBABLE IMPACTS OF THE PROPOSED DIVERSION ON QUABBIN RESERVOIR

Note: This summary does not predict the duration of the impact.

Description of Impact	Relative Probability Impact Will Occur			
	No significant change over existing conditions	Possible but Probability Low	Probable	Probability High
Increase in Nutrient Chemicals			C	
Increase in Eutrophication			C	
Modification of Present Equilibration			C	
Introduction of Undesirable Species				C[1]
Increase in Coliform Bacteria			C	
Increase in Human Pathogens		C		
Interference with Water Treatment at Quabbin			C	
Increase in Levels of Toxic Materials		C		
Increase in Levels of Radioactivity	C			
Increase in Levels of Pesticides	C			
Increase in Extent and magnitude of oxygen depletion			C	

C = Connecticut River Diversion

[1] Assuming exclusion devices were not employed.

6) Possible Environmental Impacts Caused by Construction of the Project

The preliminary design of the aqueduct and appurtenant structures of the Northfield Mountain Water Supply project precludes a detailed assessment of possible environmental impacts associated with the construction aspects of the project. If authorized, the project would undergo detailed design which could alter the preliminary design presented in this report. For example, tunnel shaft locations selected in this report may change which in turn would affect possible environmental impacts of such construction activities as tunnel spoil disposal, selection of haul roads and maintenance areas.

In response to the possible alterations in design and other followup action which might affect the environment, the Corps of Engineers requires four environmental impact statements for each project authorized. These separate statements are prepared for the Planning, Design and Construction phases and finally for the Operation and Maintenance stage. In all of the stages, projects are designed with the minimum disruption of the environment which is feasible.

This interim report of survey is a planning stage report. Detailed data, therefore, are not available on all environmental impacts which might be encountered during final design and prior to construction of the project. Sufficient information is available, however, to highlight possible areas of environmental concern which would be considered in the followup phases.

All work on the tunnel from Northfield Mountain to Quabbin Reservoir would be underground. Thus, the majority of the construction activity would not be visible or disrupting to the environment. Since the majority of the aqueduct route is in hard gneissic and other rock of good tunneling quality, the possibility of disrupting local ground water supplies is low. However, the Northfield hydroelectric facility experienced some limited disruption of individual supplies. Thus, this possibility should be assessed when the final route is selected.

Total rock spoil from aqueduct construction is estimated to be approximately 242,000 cubic yards. In the preliminary design, this quantity would require about 5 acres with a 30 foot depth. Spoil from the tunnel, however, is expected to be of good quality and some or all of the material may be recycled into other local construction projects such as road construction. This potential for recycling would depend on final design and other construction activities in the vicinity.

Surface construction activities are expected to be limited to the vicinity of the construction shafts and connecting haul roads to spoil areas if needed. Environmental impacts which should be considered in the followup phases include impact of maintenance areas, haul trucks and other associated construction needs.

In summary, detailed environmental impacts of the construction activities associated with the project cannot be fully described during the planning phase. Possible impacts, however, would be fully described in followup environmental studies conducted in the design, construction and operation and maintenance stages. Although all possible impacts cannot be quantified at this time, sufficient data exists which indicates no major adverse effects from the project. This conclusion is based primarily on the fact that the majority of construction activities would be underground. Surface construction activities may have potential impacts, but experience with similar projects indicates such impacts can be minimized through careful planning in the design and construction phases.

7) Possible Environmental Quality Enhancement

a) Environmental health of Quabbin Reservoir is presently in danger. Since 1970, water demands upon the Quabbin system have exceeded the safe yield of the Quabbin watershed. This means that on a long-term runoff basis, volume and level of Quabbin will decrease until existing inflows are augmented with new sources. To date, the reservoir has not recovered from the drought of the sixties, although 1972 and the winter of 1972 - 1973 was an excessively "wet year" and reservoir levels rose significantly.

Water quality conditions, algal growth patterns in the northern portions of Quabbin suggest that progression toward eutrophication is already taking place there. Water quality in the main body of the reservoir is still of a high quality; but if volumes decrease as projected over the years, the relative masses of high versus low quality water will shift toward an overall loss in water quality. Losses in volume will decrease the natural purification or "treatment plant" capacity and possibly the retention times of inflow waters. Losses in the hypolimnion volume will diminish the managed standing crop of salmonid fishes. The depletion of oxygen in the hypolimnion, whether partial or complete, depends a great deal on quantities of reducing agents in the water. Potential impacts on water quality are manyfold. Iron and manganese may be reduced to the ferrous and manganous state and released to the

water column. Sulfate may be reduced to hydrogen sulfide gas, resulting in obnoxious gas. In general, then, Quabbin may become unacceptable as a water supply.

When the waters from the Northfield diversion are introduced into the system, the yields of the system will again exceed the demand and levels of Quabbin will increase. With careful management and monitoring, eutrophication can be arrested and the reservoir will continue as a highly acceptable water supply source.

b) Environmental health in the communities to be serviced by the project would undoubtedly suffer without project implementation. Much has been stated previously of the economic and socio-economic impacts in the receiver area which would accompany construction of the project. Almost without exception, these impacts were of a positive nature, maintaining past progress in improving the quality of life. In addition to these economic and socio-economic gains in the receiver area, construction of the project should provide beneficial environmental impacts as well.

Therefore, the impact on the environment caused by the project can be viewed from two perspectives. First are those impacts on the estuary, Connecticut River and the receiving water bodies which would be caused by project implementation. The second perspective is the environmental impacts which would be prevented by project construction. In all cases, possible changes brought about by the project must be viewed in light of the environmental damage which could be expected without the project. Utilizing this approach, it appears environmental impacts expected with project implementation are less than could be expected without the project.

SECTION X

OTHER ALTERNATIVES

31. General

In this report, a wide range of alternatives to the Northfield Mountain Project was investigated. Included in these alternatives were other possible diversions, use of new technology as a means of augmenting existing supplies, non-structural approaches such as reduction of demand and the evaluation of the no-action alternative. A description of these alternatives and their potential as solutions to the existing problem, are given in the following paragraphs.

32. No Action

In the evaluation of this alternative, it was assumed that any failure to secure timely additional supplies for the service area will result in major economic and social losses to the entire planning region. To verify this assumption, a quantification of these impacts was necessary.

Estimates of impacts caused by a no-action policy can be expressed in two different ways. First, concrete losses without the diversion total $96 million to 1990 and $528 million to 2020, if average runoff conditions prevailed. Under drought conditions, concrete losses without diversion total $201 million to 1990 and $623 million to 2020.

As described in the previous section and Appendix K, categories included in these totals encompass industrial, city emergency, city revenue: commerce, sprinkling, business investment and domestic investment losses. However, economic losses in these categories say nothing of the ways in which the losses might be allocated. For example, of the approximately $3.5 million not collected in city revenue in 1990 by all receivers under a no-action policy, there is no way of knowing with certainty whether it would be municipal expenditures on recreation or schools that might suffer. In Section IX, this loss in revenue was expressed as 600 classrooms. Similarly, housing units not built are but an alternative manifestation of losses in the private sector.

sixty-six receiver communities, the experience of an actual municipality already beset by the kinds of problems anticipated in the event of prolonged water shortage was evaluated.

The town selected for examination was Stoughton, Massachusetts, an industrial - residential community in the Brockton S. M. S. A. An extended interview with Stoughton's Planning Board Chairman produced both background and impact information. Growth in the town has been steadily upward and shows no sign of a downward turn. The principal constraint on continuing growth may be an acute shortage of water.

The town has been searching for water since 1955 and results have been disappointing. The consequences of the resulting water deprivation have been felt across a wide range of community activities.

Although no shifts in the allocations of land use type have occurred, development in the industrial category has been nearly stopped by water shortage. Economic development has been hurt because water using industries have been turned away. This has slightly decreased the stability of the town because the tax base has not expanded quickly enough to keep up with the demands on local revenue. Wages and prices have remained in phase with the rest of the state, but taxes have increased. No Stoughton industries have left because of water shortage, but new industries have gone elsewhere. Presently, only non-manufacturing, non-processing firms are permitted to locate in town, and a $40 million industrial park is now two years behind in its development schedule.

While data projections estimated in this report show population deficits without the provision of additional supply, it does not appear, based on the Stoughton experience, that population growth is sensitive to short term controls and constraints. Stoughton's in-migration continued despite the building ban and shows signs of growing even more quickly now that new housing construction has begun again. Since the lifting of the building ban, over 500 rental units have been built and occupied. The demand for housing has lowered the vacancy rates significantly and stimulated the construction of 3,000 apartment units and the planned development of 3,000 more. Before the ban went into effect, issuances of building permits had declined for two successive years.

Because finding water has been a top town priority, other municipal services have suffered. A sidewalk program has been indefinitely postponed, and only minimal roadway maintenance and construction have occurred. Generally, expenditures have been cut as revenues

from expected property tax have dwindled. Estimates range as high as $1,000,000 in tax losses with increases in assessments covering the deficit. The cost of water has doubled in the past two years, and the municipal debt as of 1 January 1970 stood at $320 per capita. Until a mutual help agreement was reached with Easton and Sharon, adequate fire protection was a critical concern. A much needed junior high school has been put off -- an effect attributed to the "extraordinary high expenditures of finding water." As a result, the present junior high is now in double sessions.

As the search for water has become business as usual, citizens appear to have developed some tolerances for the inconvenience of watering bans. However, their latent insecurity about adequate supplies for fire protection and general domestic consumption have made water shortage a perennial political issue on which concern can focus.

Despite the general slowdown in industrial development and its second order consequences on town revenues, the average citizen perceives the water supply problem in terms of his own inability to water outdoors. Lawns and shrubbery are a waste of money, says the homeowner, and the town looks poorer for it. In turn, these feelings are reflected in attitudes about the desirability of the community as a place to live and work.

In addition to socio-economic impacts, a second major impact could occur with the no-action alternative. This second impact regards the probable deterioration in water quality within Quabbin Reservoir which could be caused by lowered reservoir volumes. As described in Section IX, Quabbin Reservoir presents a complex limnological situation. Some areas of the reservoir such as the northern sections appear to be progressing toward eutrophication. In the main reservoir body, however, quality is still high. If the pool volume decreases over the years as might occur with the no-action alternative, then there will be a shift towards an overall loss in water quality in the reservoir. Losses in volume will decrease the "treatment plant" capacity and hypolimnion volumes affecting water quality from both an environmental and public health standpoint.

Based on the evaluation of the socio-economic and environmental impacts, the no-action alternative has many disadvantages. Use of this alternative, therefore, does not offer a realistic solution to the short range needs of the study area.

31. Weather Modification

The primary source of the water used for public and private water supply in Massachusetts, as in most humid areas, is precipitation falling directly on the areas concerned. It follows then that if precipitation can be increased in a regulated manner, the water supply can also be increased. To this end, several major agencies such as the National Oceanic and Atmospheric Administration (NOAA), the United States Bureau of Reclamation, the American Meteorological Society, and the National Science Foundation are investigating ways of productively modifying natural precipitation patterns. The primary focus of research is in the area of cloud seeding. Other fields of interest are long-term seasonal precipitation forecasting and fog drip augmentation. Since little work has been done on the latter two, and what little has been accomplished is not applicable to the Massachusetts area, only the process of cloud seeding will be reviewed in this section.

A. Cloud Seeding

Simply stated, rain falls from clouds when water vapor in the clouds condenses around nuclei and forms rain drops large enough to overcome frictional resistance to falling. In technical terms, this process is the conversion of the water vapor from a state of colloidal stability to one of colloidal instability. The concept of artificially induced precipitation by cloud seeding refers to the introduction of particles of foreign substances, such as dry ice and silver iodide into clouds to serve as condensation nuclei. Theoretically, this action will result in condensation of the water vapor and consequent precipitation. In short, it is scientific rain making.

The testing of the engineering and economic feasibility of this theoretical process has been concentrated in experimental projects in the Rocky Mountain and Upper Great Plains regions. Evidence gained through NOAA research suggests that winter cloud systems over Lake Erie may be modified to produce additional precipitation. A cost benefit study was performed for the Connecticut River Basin, but this study was in design only with no actual experimental work involved. Most information regarding the potential of cloud seeding in the eastern United States is derived from commercial cloud seeding operations.

Some of the findings resulting from these studies and experiments are summarized below:

1) The state of the art is such that most researchers look upon the potential of increased precipitation through cloud seeding with

an air of cautious optimism. Study to date, however, has provided little more than a beginning to the solution of many of the problems involved in weather modification.

2) Cloud seeding is impractical during severe drought conditions when water shortages are most critical. The first requisite for cloud seeding is the presence of clouds, and droughts are notable for their lack of clouds. Present technology is not even remotely capable of producing clouds by weather pattern modification. During a temporary interruption of drought conditions, clouds may form over an area. Even under these conditions, however, cloud seeding would not appreciably alleviate water supply problems since most precipitation would be in all likelihood taken up immediately by plants and soil. It is apparent then that water shortages in periods of drought cannot be solved by cloud seeding. Any substantial seeding induced precipitation would have to be produced during non-drought conditions with abundant moisture in the atmosphere.

3) There are many problems that must be solved before substantial technological breakthroughs result. One of the most critical is the inability of researchers to satisfactorily define optimum cloud conditions and seeding techniques and to predict seeding results accurately. In other words, there is an inadequate understanding of the basic cloud processes which determine: a) the "seedability" of a cloud or cloud system, and b) the proper seeding treatment to stimulate rainfall production efficiently in a potentially seedable cloud.

Another problem is the possibility of undesirable effects of seeding. Indiscriminate seeding might increase soil erosion and sedimentation in streams through intensification of the normal rainfall rate of natural storms. There is the possibility also that artificial seeding of clouds might in fact reduce the natural rain producing capacity of the clouds.

4) Estimates of the feasibility of cloud seeding in the eastern part of the country, including New England, are vague and poorly defined. Most recent cloud seeding research has been conducted in the western states. Atmospheric scientists have cautioned that results of seeding experiments in one area of the country must be viewed with caution when applied to other areas characterized by different topography and climate. It is apparent that much research needs to be done in the eastern part of the country. There is data available for parts of this area from commercial cloud seeding operations. However, these operations were not performed under proper scientific and statistical control procedures and any data gathered in such a manner must be used and interpreted with care.

B. Conclusion

Research has continued to improve the state of the art of weather modification by cloud seeding and other means. At best, however, weather modification is still an inexact science. Studies are unable to predict optimum cloud conditions and seeding results with any degree of accuracy. It is the conclusion of this section, therefore, that at this time weather modification operations to augment water supplies in Massachusetts does not appear to be a viable solution to the immediate water supply problem.

32. Desalinization

Desalinization, the process in which brackish and salt water is converted to fresh, is currently being used in some parts of the world as a viable, economically feasible source of fresh water. This process thus was considered for its potential as a future alternative solution to the water supply needs of eastern Massachusetts.

The conversion of saline to fresh water is accomplished through four major processes: distillation-evaporation, membrane separation, crystallization, and chemical differentiation. A descriptive summary of each process is given below.

A. Distillation-Evaporation

In this process, water containing salt or other impurities is heated and vaporized. The water vapor, free from the salt and other solids which remain behind as the water boils, is then condensed and collected. The system is basically a simple one requiring only a source of heat energy to boil the water, a method of cooling the water vapor (condensation) and various kinds of plumbing and receptacles for the transfer and storage of the water.

Since distillation, by its nature, results in the complete separation of the water vapor from the dissolved salts of the influent, the process produces fresh water of exceptional purity. Because this method removes the water from the salt, rather than vice versa, the quality of the influent is not critical and the system works equally well on water with a high salt content as an only slightly brackish water. For these reasons, among others, distillation is the oldest and best-known process of desalinization.

B. Membrane Separation

Desalinization by the membrane process is based upon the ability of thin membranes to pass molecule of pure water and retain the ions of salts and other dissolved solids. There are three basic variations to this concept: a) electrodialysis, b) transport depletion, and c) reverse osmosis. The first two variations depend on the electrical properties of the ions involved, while the third depends on a pressure differential existing across the membrane. Of these three variations, the electrodialysis process is the most well established, with many commercial installations throughout the world.

In contrast to distillation, the membrane process separates the salt from the water rather than the water from the salt. Each stage of the electrodialysis process removes slightly less than 50% of the dissolved solids in the water being treated. The more saline water, the more stages are needed and hence more energy is consumed. For this reason, electrodialysis and other variations of the membrane process are more economical when used with brackish water with a salinity of between 5,000 - 10,000 mg/l, as opposed to more saline water. The water can then be refined in stages to the desired degree of purity.

C. Crystallization

This process relies primarily upon the fact that as water freezes, the ice crystals reject ions of salt. Saline water is frozen and the crystals of pure ice are then skimmed or removed for later use from the still liquid brine. A second method of separation by crystallization employs the hydrate process which is the formation of a crystalline substance by the combination of water with low molecular weight, hydrocarbons or their derivatives. Like ice crystals, these hydrates reject salt ions. It takes less energy to freeze water than it does to boil it, thus this method has an advantage over distillation in that it consumes less energy. The crystallization process has not been widely used, however, and further research into its effectiveness is continuing.

D. Chemical

In this process either the water or the dissolved salts are made to undergo a chemical reaction which forms a substance which can be easily separated from the untreated water. Ion exchange, a method by which the saline water is passed through treated resin and the salt ions selectively removed, is the most widely used method of chemical desalinization.

The efficiency of ion exchange decreases with time as the "holes" in the resin become filled with salt ions. Once the resin is saturated, the operation must be closed down and the resin regenerated. For these reasons, the process has had only local exposure and small volume use.

E. Present Application

Sea water can be considered, for all intents and purposes, an unlimited source of fresh water once the technology of desalinization is refined to a point where it is economically feasible. To this purpose, the federal government, through the Office of Saline Water, has promoted extensive study and research into the problems of desalinization. Several model and testing plants and facilities have been constructed to aid in these

studies. The research to date concludes that of the four main processes discussed above, distillation and membrane separation are best suited to large capacity plants. Economical considerations dictate that distillation is best for sea water and electrodialysis for brackish water.

Presently more than 300 million gallons per day (mgd) of desalting capacity is installed world-wide. Plants are generally located in arid regions where conventional water sources are high cost or unavailable. Principal areas of use are in the Mid-East and Caribbean tourist islands. In the United States, desalting for municipal water supply has thus far been limited to smaller communities, relatively isolated from sources of conventional supply.

The largest municipal desalting plant in the United States is a 2.6 mgd distillation process in Key West, Florida. Largest in the world is a French-built, 30 mgd distillation plant, recently completed in Kuwait.

A distillation plant was recently proposed for San Louis Obispo and Santa Barbara Counties, California, which would have a capacity of 40 mdg. Construction on this plant which would have been the largest in the world was scheduled to begin in 1973, however, action on this plant has been recently suspended.

F. Costs of Desalinization

The cost of fresh water produced by desalinization depends upon the capacity of the plant, the type of process used and whether nuclear or fossis fuel is used. In general, the larger the plant capacity, the less the cost per unit of water. As has been mentioned previously, distillation is more economical for the desalting of sea water, while electrodialysis is better for brackish water. The water costs from nuclear fueled plants are approximately 10% less than from fossis fuel when used in large capacity (more than 100 mgd) plants.

The current cost of desalting is about one dollar per thousand gallons. This estimate is based upon an output capacity of 1 mgd, an amount representative of many plants currently in operation. Designs for the larger plants, such as for San Louis Obispo and Santa Barbara Counties, California, indicate costs in the vicinity of 73 cents per thousand gallons at the plant site. To this figure must be added delivery system costs.

G. Conclusion

Desalinization by numerous processes is already feasible in parts of the world when the natural water supply is either scarce or of poor quality. In these areas, the relatively high costs of water produced

by desalinization are justified. Research[1] has indicated that when larger capacity plants are designed and in production, the costs for desalting sea water could ultimately be reduced to approximately 50¢ per thousand gallons, in the size range of the Northfield Mountain Project, although the proposed California plant would produce water at 73¢ per thousand gallons at the plant site. Even at this reduced cost, however, desalinization is not competitive with present costs of developing natural surface and sub-surface water supplies. For example, costs of water from this report's recommended project is about 15¢ per thousand gallons.

Aside from the economic costs involved with desalinization, the Office of Saline Water is also investigating the potential hazards to the environment which might occur. In considering placement for any type of desalting plant, environmental factors are as important as any other factor. Pure water is not the only product. A plant will produce extremely concentrated brine as an effluent, plus any waste products from the power source, such as soot, heat, smoke, toxic gasses, etc. So far as brine is concerned, this brine from distillation plants is of high temperature, higher chloride content and may contain concentrations of copper, all of which may prove injurious to the environment. Special design procedures would be required in the cases of estuaries or areas with restricted water interchange, as many life forms present might be adversely affected. Two land methods of disposal have been studied: (1) evaporation to dryness; and (2) deep-well injection. Evaporation is expensive, though this is highly dependent on land costs, presently quite costly in urban areas. Injection method costs are estimated at 25 to 70 cents per 1,000 gallons of brine. Such costs must be added to plant production and distribution costs to arrive at a true cost of water from this technology. At present, the Office of Saline Water is investigating other methods of brine disposal.

The future of desalting in the northeast is described as follows by the Office of Saline Water:[2]

"Existing desalting operations are characterized by several constraining features. Among the most important are high total annual costs, relative to conventional water sources; the need for proof of large-scale plant operation; and the problem of brine disposal. In the future,

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[1] Based on data contained in memorandum from Office of Saline Water to New England Regional Coordinator, U. S. Department of the Interior, 17 August 1972, based on 1972 price levels.

[2] Ibid.

as technology is further developed, several of the constraints will be lessened, and desalting may prove to be an attractive supplement to water supply in coastal and estuarine areas of the Northeast United States. Desalting processes may also serve future use as an aid in control of water quality." As a result, this report concludes that desalinization not be considered at this time as a viable alternative source of water in eastern Massachusetts for the short-range water supply problems. When and if the technology and efficiency of this process is refined so that it is economically and environmentally competitive with other methods of supplying water, its feasibility can be re-evaluated.

33. Importation

During the crisis years of the sixties' drought, many newspaper and periodical articles pondered the possibility of diverting water from extra-regional sources as a solution. One of the major basins often mentioned as a water supply source for the Northeast was the Saint Lawrence. As an alternative to developing local resources to meet future water needs, an investigation was made regarding the feasibility of diverting Saint Lawrence flow to meet future needs.

The Saint Lawrence River Basin is an impressive basin, both in its size and the annual runoff from its watershed. The drainage area is about 295,000 square miles at Ogdensburg, New York, which includes over 95,000 square miles of water surface area, most of which is in the five Great Lakes. Storage capacity within the lakes regulates the flow in the river to a large degree. The long term average discharge at Ogdensburg is about 240,000 cubic feet per second (155,000 mgd). From a review of these statistics, it is apparent that the basin, if developed, could meet the forecast supply demands for all of southeast New England.

Engineering studies were conducted to assess various methods and quantities of development from the basin. Cost estimates were prepared for projects which would service all of the Northeast through the year 2020. Construction costs for such facilities were estimated to be as high as 8.5 billion dollars, excluding any necessary water treatment costs. Water delivered from such an undertaking would cost substantially more than similar volumes made available from local resource potential.

In addition to the high cost of water, this alternative also has several other major disadvantages. First, the nature of the project would not allow stage development. Thus, large expenditures of funds would be required for distant long range needs. Second, since the basin is international, negotiations with Canada would have to be held and a treaty consummated prior to diversion. Assuming that Canada would be favorable to such negotiations, at best, any treaty would be in the distant future.

Based on the results of investigations conducted as part of this report, the importing of water to meet short-range water supply needs does not present a viable alternative for the southeastern New England Region.

34. Waste Water Reuse as a Municipal Supply

Waste water reuse, especially in industrial process application, has been economically successful in many sections of the country. The Bethlehem Steel Company in Baltimore, Maryland, currently uses about 120 mgd of treated municipal waste from Baltimore and uses this effluent in its quenching and cooling processes. The Dow Chemical Company uses treated sewage from the City of Midland, Michigan for use in its cooling water and fire protection system. In Amarillo, Texas, effluent from the municipal sewage treatment is used as cooling water and boiler make-up water for industries located in that city.

Other uses to which treated waste water has been applied include irrigation of both crop land and lawns, as a fresh water barrier against salt water intrusion, and in some cases as a source of supply for formation of recreation lakes and ponds.

Direct reuse of waste water effluent as a public water supply, however, has not been utilized to a large degree. Advanced waste treatment research and development programs at the Federal level are continuing and pilot plant studies such as the noted Lake Tahoe project are apparently meeting with success in producing a high quality effluent.

The current Drinking Water Standards do not apply to direct reuse of reclaimed water for drinking. In a series of recent articles, the Division of Water Supply Programs, Environmental Protection Agency, (formerly Public Health Service) have described a number of potential health programs which could occur with the use of renovated waste water. As stated in these articles, recent public repercussions from birth defects caused by thalidomine and from the side effects of other

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new drugs, underscore the responsibility that health officials have in introducing or promoting the use of reclaimed waste water as a domestic source.

Health officials feel that many questions remain unanswered which must be fully investigated if renovated waste water is to be considered for drinking water purposes. Research considered vital was described in an article [1] prepared by the Director and Deputy Director, Division of Water Supply Programs. In their article, it was stated that "before development of intimate personal-contact uses of renovated waste waters, one needs to:

A. Initiate studies on viruses for:

1) Development of improved viral detection and enumeration methodology.

2) Exploration and definition of the basic properties of enteric viruses.

3) Provision of knowledge on transmission of viruses through the aquatic environment.

4) Definition of the impact of viral disease on man through associated epidemiological studies.

5) Development of technology for the positive removal and inactivation of viruses.

B. Investigate the potential problems from bacteria and other microorganisms in reclamation systems.

C. Identify and define the potential health effects of organic and other chemicals not removed by reclamation plants and subject to build-up, and develop techniques to identify and measure readily the concentrations of such chemicals.

D. Dispel the cloud that hangs over the whole subject of reliability for wastewater-treatment-plant operation. Reclamation plants for direct reuse must have fail-safe processes, back-up facilities, alternate means for disposal, continuous monitoring, and bioassay, and they must be operated in an atmosphere that demands reliability. State programs responsible for the operation of wastewater treatment plants

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[1] Lang, W. N. and Bell, F. A., "Health Factors and Reused Waters," Journal American Water Works Association, April 1972.

will require upgrading. Pilot and field-scale testing will be required for the validation of processes and practices prior to their widespread use.

E. Use common sense. Renovated wastewater should not be used for the ultimate personal use -- as a drinking-water supply -- until there is no other practical choice; and then, hopefully, the minimum research will have been completed and the use will be carefully operated and controlled. Meanwhile, in water-short areas, the renovation and reuse of wastewaters for industrial, limited irrigation, and other low human-contact purposes should be investigated and advanced.

The future of direct wastewater reuse, particularly in industrial applications, seems promising. Future water demand forecasts for industrial usage used in this report, in fact, anticipates greater recycling of water in the industrial sector. For example, industrial output projections of Standard Industrial Classification (SIC), category No. 28, Chemicals and Allied Products, indicate a 750% increase by 1990. Thus, if no recycling beyond that presently practiced were implemented, then anticipated water supply needs for this industry would increase over sevenfold. Future industrial supply estimates developed for this report, however, recognize many pressures are being exerted which should alter present industrial water use practices. In the SIC 28 category, described earlier, the possible changes in use practices were estimated to require a 370% increase in supply rather than the 750% which might be expected based on output forecasts.

Use of renovated waste water as a regular domestic supply, however, requires full results of proposed research. Until such research is completed, wastewater reuse as a municipal water supply is not a viable alternative to meet short-range supply needs.

35. Ground Water Resources

A study[1] of the ground water resources of Massachusetts was prepared for the Corps of Engineers by the United States Geological Survey. The study was based upon analysis and interpretation of available data and did not include any new exploratory work. The objectives of the study included an estimate of the area extent and sustained yield of principal aquifer reservoirs which might be used for supplementing municipal and industrial water supplies. The cost of producing the water was also estimated.

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[1] This investigation was conducted as part of the feasibility study of potential engineering alternatives in the study area.

A. Occurrence of Ground Water

A water bearing strata of rock material is called an aquifer. The principal aquifers underlying Massachusetts are of three types: 1) Stratified drift, layers of sand and gravel commonly interbedded with some silt and clay; 2) till, a non-stratified, poorly sorted mixture of clay, sand, gravel and boulders; 3) crystalline metamorphic and igneous bedrock. Till and bedrock aquifers yield small amounts of water, suitable only for domestic supplies. Only those aquifers occurring in stratified drift have the potential capacity to sustain large withdrawals of water.

Geologic reports and well logs were studied to determine the distribution and thickness of stratified drift deposits in Massachusetts. Deposits were found about everywhere in the state, but were most extensive in the valleys and outwash plains of the east and southeast area.

B. Hydrologic Parameters

In order to evaluate the aquifers as potential sources of water supply, their water transmitting and storage characteristics were studied. Permeability values, in gpd/sq. ft. were assigned to various lithologies such as gravel, sand and gravel and coarse - medium - fine sand on the basis of the relationship between grain size and permeability. The transmissibility, in gpd/ft., of a lithologic unit was then determined by multiplying the thickness of the unit by its permeability value. Coefficients of transmissibility and storage were also calculated from controlled pumping and drawdown tests at wells sunk in the aquifers.

The saturated thickness of the aquifers was mapped where data was available. The thickness was determined by subtracting the elevation of the base of the aquifer from the water table elevation. The saturated thickness of stratified drift, although not necessarily indicative of the presence of permeable zones, has been found by investigators to be a useable favorability guide for a general analysis of the ground water withdrawal potential. One further indicator of the water content of a ground water reservoir is the percentage of surface stream flow which is contributed by ground water. This portion of stream flow is termed base flow or ground water runoff. Analysis of past records indicates that average annual base flow of a given stream is approximately equal to Q-60 (stream flow equalled or exceeded 60% of the time) in a year of normal climate and equal to Q-70 in a dry year. The Q-70 flow is considered an index to the amount perennially available for consumptive use without depletion of storage.

The hydrologic criteria described above were applied to the principal aquifer reservoirs of Massachusetts. In this manner the capability of these reservoirs to serve as alternate sources of water supply could be evaluated. The rates of withdrawal from the aquifers were estimated by assuming the following conditions:

1) No recharge occurs for 200 days in dry years and all the water produced during this period is from ground water storage -- it is assumed that reservoirs capable of sustaining withdrawals under these conditions could continue producing forever;

2) The configurations of the reservoirs were idealized to form elongated rectangles;

3) A system of dewatering wells, 24" in diameter and spaced 2,000 feet apart for 2 mgd yields and 1,000 feet apart for 1 mgd yields, was hypothesized to aid in planning and cost estimates;

4) These wells were assumed to have no drawdown attributed to partial penetration, thinning of the reservoir, nor well losses;

5) Available drawdowns in the wells were limited to two thirds of the saturated thickness for water table conditions and to the top of the producing reservoir for artesian conditions;

6) Current withdrawals of ground water were included as a part of the estimated withdrawals.

The results were then tabulated by area and rate of withdrawal in mgd/sq. mile and total withdrawal in mgd.

C. Conclusions

The survey of ground water resources indicated that the aquifers in Plymouth County and parts of Cape Cod have the capacity to sustain long term, large magnitude withdrawals. The water demand on Cape Cod is increasing at a fast rate; therefore, this area is not considered in this report. The Plymouth County area studied comprises 300 square miles and its estimated safe yield is 300 mgd. This estimated rate exceeds the required quantity established as a goal at this study. Thus, it was concluded that the Plymouth County area could offer a viable alternative source of water supply for eastern Massachusetts.

Cost estimates for the necessary resource development were then prepared. Major development items included in these estimates were land

acquisition, cost of ground water well development, water treatment facilities, pumping installations and connecting aqueduct system to the metropolitan service area. The estimated construction cost for the ground water development per million gallons per day (mgd) capacity is about 1.2 million dollars. Costs for the Northfield Mountain Project on the other hand are estimated to be about 600,000 per mgd capacity. Annual costs of ground water development which include interest and amortization; maintenance, repair and operating cost; and major replacement costs are estimated to require charges of about 30¢ per 1,000 gallons produced. Annual costs for Northfield Mountain would require about 15¢ per 1,000 gallons produced.

In addition to the economic costs associated with development of the ground water alternative, there are also potentially significant environmental and socio-economic impacts. For example, land taking activities associated with sanitary protection of the various wells may be substantial. Preliminary estimates of necessary land acquisition for the wellfield development indicate 1,000 to 1,500 acres of land would be necessary. This compares quite unfavorably with the 30 acres estimated to be required for the Northfield Mountain Project.

Connecting pipelines between wells in the wellfield and transmission facilities to point of use would require a large amount of surface construction. Such extensive surface construction would have an impact on the environment in the vicinity of the wellfield and transmission facilities. Since portions of the aqueduct systems would pass through heavily urbanized areas, disruption would be expected to be extensive.

Since all water developed from the wellfield would have to be pumped to the consumer, this alternative would utilize large amounts of electricity. Thus, depending on the method used to provide this power, impacts on the environment may be expected. The Northfield Mountain Project would utilize off peak power; therefore, no additional potential environmental damage would accrue because of power requirements.

On the basis, then, of cost comparisons and potential socio-economic impacts, use of ground water does not appear to offer an attractive alternative to the proposed project.

38. Dual Water Supply Systems

An alternative which has been receiving attention of late has been the use of dual water supply systems. In these systems, a hierarchy of

water supply would be established whereby higher quality supplies could be used to furnish a potable source for drinking, cooking, dishwashing, cleaning, bathing and laundering. All other uses could be furnished by a second supply of lesser quality.

Two general methods have been suggested for such a dual system. The first is the possibility of recycling at the point of usage. Under this scheme, drinking, washing and bathing water would undergo treatment and then be further utilized as toilet flush water and outdoor uses. It is estimated that such a system could reduce domestic water use by as much as 50%.

Various systems for in-house reuse or for outdoor usage have been proposed and some are being marketed on a small scale.

Advantages to this system beyond potable water consumption reduction is the reduction in sewage water volume, sewer pipe and pumping requirements. Capital cost outlay for such a system based on limited cost data would be over twice as expensive as water delivered from this report's recommended project. Other disadvantages to this alternative lie with its limited application and accompanying operational experience, potential problems of odor and other aesthetic considerations. Health officials, in general, have not expressed their acceptance or rejection of such systems. However, their general apprehension on introducing less than potable water into the home environment could also reasonably be expected with regard to any system of this nature.

The second method which has been suggested for delivering higher and lower quality water for various uses would require a second distribution system. This second distribution system would carry river water or even sea water to supplement the high quality primary supply source.

Two methods of providing the second (lower quality) distribution system could be employed. The first would involve installation of the entire system immediately. The second, and more practical, method would be on an incremental approach wherein secondary systems are installed in new or replacement buildings above a certain size. The second approach was evaluated in this report. With this approach, water consumption is only reduced at a given time by the building construction that utilizes secondary systems.

To estimate costs for such a system, a report on the New York City area prepared as part of the NEWS Study was utilized. Based on the results of that investigation, preliminary capital cost estimates for

such a dual system would be about 6.5 million dollars per mgd saved. The Northfield Mountain project recommended in this report is estimated to cost about $600,000 per mgd. Therefore, it is quite apparent that use of a dual supply distribution system as an alternative would be an extremely expensive alternative.

In summary, then, use of dual water supply systems does not offer an alternative to the recommended project in this report. Of the two methods, the system which would recycle water at the point of usage holds the more promise for future application.

39. Other Diversion Sites

In addition to the Northfield Mountain Diversion proposal described in this report, a number of other diversion possibilities were also evaluated. These other possible sources included diversions from: the mainstem Connecticut River at other than the Northfield Mountain location; other tributaries of the Connecticut River; the mainstem of the Merrimack River and the Sudbury River, a tributary of the Merrimack, formerly used by the MDC.

A. Other Connecticut River Basin Alternatives

The possibility of diversions from the Millers River sub-basin appears to offer a viable companion source which when combined with the yield of the Northfield Mountain Project would allow the system to meet its short and medium range needs. Development of the Millers River is the subject of another Interim Report of Survey.

Alternative methods of diversions from the Connecticut River Basin, such as the Deerfield River or another location on the Connecticut River, could provide an equivalent yield to that of this report's recommended project. Development of either of these proposals, however, would be more expensive than either Millers River proposals or Northfield Mountain. Aside from economic costs, neither alternative appears to present any clear cut advantage from either an environmental or socio-economic standpoint. It appears then that development of these alternative sources would offer an opportunity for providing the necessary short-range water supply needs. Their development, however, would be more expensive and would not offer any advantage over the project recommended in this report.

B. Merrimack River Basin Alternatives

1) Merrimack River Mainstem

As an alternative to further diversions from the Connecticut River Basin, the potential of developing the Merrimack River mainstem was also investigated. Based on studies to date, use of the Merrimack River, to meet future needs, holds promise. Use of the river to meet immediate needs, however, does not appear to offer an alternative from either an economic or public health standpoint.

At present, the physical, chemical and bacteriological quality of the river is poor. For years the river has been subject to major discharges of municipal and industrial wastes. Because of these discharges, the Merrimack is often characterized as one of the ten most polluted rivers in the United States.

Even with the existing pollution load, the mainstem river is now used as a water supply for the Cities of Lowell and Lawrence. Water treatment facilities for both municipalities are conventional; however, taste and odor problems are experienced periodically at both locations.

Pollution abatement programs to implement secondary waste treatment facilities on point sources of pollution are under way by State and Federal agencies. Costs of these plants are estimated to be 235 million dollars. Upon completion of the abatement programs scheduled for 1976, the river will be improved as a water supply source.

A recent report by the Corps of Engineers,[1] in cooperation with the Environmental Protection Agency, investigated the feasibility of various alternatives for upgrading treatment processes beyond the planned implementation schedule. Cost estimates of the various alternatives ranged from 668 to 1108 million dollars. All of these plans would further enhance the quality of the river for use as a water supply source.

At present, the NEWS study is performing an Interim Report of Survey on those waste water treatment alternatives reported upon in the waste water feasibility report. The objective of this task is the evaluation of the various alternatives for their effectiveness in meeting the goals of the 1972 Water Quality Act. As a companion effort to the waste water element, investigations in survey detail on the river's potential for water supply development are also under way.

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[1] "The Merrimack: Designs for a Clean River," North Atlantic Division, Corps of Engineers, September 1971, Northeastern United States Water Supply Report.

In summary, at present, the Merrimack River Mainstem in Massachusetts is generally of poor quality. Alternative methods of treating the waste water discharges were assessed in a feasibility report by the NEWS Study. Followup survey detail investigations on alternative waste water treatment techniques and methods for developing water supply facilities are presently under way.

Based on studies to date, use of the Merrimack River to meet future water supply needs holds promise. Use of the River to meet immediate needs within the study area does not appear to offer an alternative to this report's recommended project from either an economic or public health standpoint.

2) Sudbury River

In 1846, the Cochituate Reservoir (previously Long Pond and presently Lake Cochituate) was acquired and developed to meet Boston's water needs through diversions from a subdivision of the Sudbury River watershed.

In 1872, the Sudbury River Act was passed which authorized the diversion of a portion of the Sudbury River waters to the Boston Water System. Subsequent to this Act, a series of reservoirs were construced by the Boston Water System and later by the Metropolitan Water District to develop the watershed. Construction on the last reservoir in the basin was completed in 1898 and a total of 75.2 square miles of drainage area was controlled.

In 1947, in response to the availability of supply from Quabbin Reservoir and the higher quality supply from this source, the Massachusetts Legislature transferred control of a number of the reservoirs to the Department of Conservation. The reservoirs transferred represented about 50 square miles of drainage area and were subsequently developed for recreational usage and their water supply use discontinued.

With its available supplies unable to meet its short range needs, the Metropolitan District Commission has reevaluated the potential which the full Sudbury system may have. Based on initial studies, it appears an additional 40 million gallons per day may be made available through flood skimming techniques.

The Sudbury Basin waters, however, have a number of water quality problems. Thus, to provide the potential yield, water treatment facilities would be necessary. Preliminary cost figures for needed facilities are estimated to be about 43 million dollars. In addition, transmission and pumping facilities may be necessary.

In order to fully estimate the potential and costs for redeveloping the Sudbury system, the MDC is preparing to initiate detailed investigations.

In summary, the "redevelopment" of the Sudbury River Basin could add an attractive increment to the available water supplies for this report's study area. Based on preliminary cost estimates, this increment is expected to cost about twice that of this report's recommended project. Yet to be determined as part of the MDC further study are the environmental and socio-economic advantages and shortcomings.

C. Conclusion

Alternative development of the Connecticut or Merrimack Rivers was evaluated as methods of meeting short range water supply needs forecast. Although either river basin offers opportunities, their development would be more expensive than the proposed project. In addition to economic considerations, use of the heavily polluted Merrimack River does not appear to offer an attractive alternative from a water quality standpoint for immediate supply needs.

The Sudbury system plan needs further study for a full assessment of its potential. If the Sudbury "redevelopment" plan were to be found attractive and constructed, however, it would be fully compatible with this report's recommended project.

38. Water Demand Control

The NEWS Study, cognizant of the narrow margin separating available yield and consumer demand, conducted studies on methods available to alleviate this critical water supply situation. Two general approaches to the problem were investigated: the first considered various methods of increasing the supply available to the system. The second approach described in this section was investigation of methods whereby demand could be curtailed.

A. Components of Demand

1) General

Water demand can be classified into four main categories. These are Domestic, Public, Commercial and Industrial. Nationally, of water withdrawn from public systems, 47 percent is delivered to domestic consumers; 13 percent to public uses; 18 percent to commercial; and 23 percent to industrial applications. A description of uses to which water is applied in the various categories is given in the following paragraphs.

2) Domestic

Domestic use, for purposes of this study, includes that water used by the consumer both within his home and that used by him for allied residential uses such as lawn sprinkling and car washing. In house uses of water include drinking, bathing, cooking, washing, and carrying away of wastes.

Total domestic water use in the United States amounts to approximately 73 gpcd. Few studies have been conducted regarding the composition of this demand; however, the U.S.G.S. reports domestic water in Akron, Ohio, was used in the following proportions:

TABLE 18

Domestic Water Use

Carrying away of wastes	41%
Bathing	37%
Cooking and Washing	9%
Drinking	5%
Clothes Washing	4%
Lawn Sprinkling	3%
Car Washing	1%
Total	100%

3) Public

Public or municipal use on a national basis accounts for about 28 gpcd of the average 157 gpcd supplied by public water utilities. Water used in this category is delivered to municipal facilities such as administration buildings, schools, hospitals, golf courses and other facilities used by the community at large. The water delivered in this category, of course, reacts to number and type of services provided. In Boston, for example, with a large number of hospitals and other institutions, it is reported 38 percent of total water use falls within this category. In Wellesley, a suburb of Boston, only 9 percent is recorded as public.

4) Commercial

A significant portion of all water delivered from public supply systems is used by commercial establishments. Nationally, it is estimated about 28 gpcd are used for this purpose. Within this category, is included department stores, restaurants, hotels, laundries and other service elements which serve the general public. No breakdown of water delivered to the commercial sector was available for the Boston Metropolitan area, but it is estimated 850,000 commuters travel daily to the City of Boston. Water supplied to these commuters for their needs while "temporary residents" cannot help but be a significant share of the water supplied to the City.

5) Industrial

Many industrial establishments obtain their water supply from public utilities. Of the average 157 gpcd recorded in the United States, 36 gpcd were used in industrial plants. The water withdrawn by these industries is used for three principal reasons: cooling water; boiler water or water used for the generation of steam and process water, which is water that comes in contact with the product being manufactured.

Available records on industrial use which record individual community usage are limited. On a state-wide basis, about 100 mgd or 13 percent of the publicly supplied water was drawn for industrial use in 1968. Within the MDC service area, a recent telephone survey conducted by the NEWS Study indicated about 8 percent of water withdrawn was used for industrial. On this basis, then, Massachusetts and the MDC service area are not heavily industrial water users if compared to the national percentage of 23 percent.

B. Methods of Controlling Demand

There are basically five methods which have been suggested as effective in controlling demands on water supplies. These are:

a) Changing from flat-rate to metered supply
b) Increasing the price of metered supply
c) Imposing of restrictions on water use
d) Utilization of water saving devices
e) Public water conservation education programs

Each of these methods outlined above are described in the following sections as they might apply to the demand forecasts prepared for this report.

1) Metering

The installation of meters which measure the amount of water used by a consumer have been shown to be effective in varying degrees in reducing demand for water supply. With metering, the customer is now charged for the quantity of water used, instead of being charged a flat rate for a period of time regardless of quantity used. Most of the studies conducted regarding the effects of metering indicate domestic in-house use is relatively in-elastic, but lawn sprinkling use and some industrial applications apparently are affected.

Use of metering then appears to present a good opportunity for conservation of a resource. In the Boston area, however, application of this technique to reduce demand is quite limited. Most municipalities in eastern Massachusetts already meter extensively. For example, the MDC system is presently 96 percent metered. Complete metering, therefore, would affect only 4 percent of service connections in this system and not, therefore, affect to any significance water supply demands forecast in this study.

2) Pricing Effects on a Metered Supply

a) General

A number of articles have appeared in recent years in water supply and water resource professional journals regarding the impact of price increases on water demand. All of these articles attempt to quantify the constraining influence which pricing may have upon demands. In these articles, a number of various pricing techniques have been suggested for administration of price hikes. These include general increases in price levels, seasonal pricing and increasing block rates for varying usage of water. Aside from the administrative technique employed, however, the objective of the articles is to define impact of price increases on demand. Generally, the authors, however, are forced to base conclusions on a generally incomplete and sporadic empirical data base. In the following paragraphs, a brief description of some of the major empirical studies is given. Following the study descriptions, an application of the empirical data findings to the eastern Massachusetts forecast demand is made for both the domestic and industrial water components. Finally, an attempt is made to correlate the results

of the empirically derived data to the local water supply system experiences. Although the data presented later is applicable to general pricing increases, the conclusions are felt to apply regardless of administrative technique selected.

In 1957, H. F. Seidel and E. R. Baumann[1] prepared a statistical analysis of various water works data. In their analysis, the authors derived an elasticity coefficient of 1.0 for certain price levels and a lower, inelastic coefficient for lower price levels. The authors, however, noted that they remained skeptical that a rate adjustment has the prompt, proportional effect on water use which the elasticity coefficients suggest. They stated their review revealed that most rate adjustments are moderate enough and water use habits sufficiently stable to consign the rate factor to a "distinctly minor role as an influence on fluctuations in water use."

Linaweaver, Geyer and Wolff,[2] during the years 1961 - 1966, conducted studies to determine patterns of residential water use and factors influencing this use. The results were then used to determine design criteria for water supply systems. These studies were sponsored by the Technical Studies Program of the Federal Housing Administration, and were in cooperation with sixteen water utilities in various climatic regions. Both residential and apartment areas were studied. Climate, economic level of consumers, and pricing systems were considered and concluded as having in that order the major influences on water use.

The economic level of the consumer was considered to influence water use for several reasons. A consumer in a higher valued area is likely to have more water using appliances which increase the overall domestic use. A second reason advanced is that a higher-priced house usually has a larger lawn which will increase the sprinkling demand. Climate is a major factor influencing sprinkling use when there is a lack of precipitation, but it has little effect on in-house use.

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[1] Seidel, Harris F. and Baumann, E. Robert, "A Statistical Analysis of Water Works Data for 1955," Journal of the American Water Works Association, XLIX, No. 12 (December 1957).

[2] Linaweaver, F. P., Jr., Geyer, John C., and Wolff, Jerome B., A Study of Residential Water Use, Washington: Department of Housing and Urban Development Report TS-12, February 1967.

The cost of water also influences the demand. Based on their findings, the authors conclude that cost does not influence in-house water use to a great extent, but would decrease sprinkling use.

Howe and Linaweaver,[1] using the results of the Residential Water Use Study,[2] studied the effect of water pricing in residential areas. Included in the results of this study was the formation of two equations which, according to the study, described the relation of price on use.

The domestic in-house demand was considered best expressed by the following linear equation:

$$g = 206 + 3.47v - 1.30p$$

where g = gallons per day per dwelling unit
v = market value of dwelling unit in thousands of dollars
p = price per 1000 gallons in cents

By use of this equation, the authors concluded that the effect of price on demand and the price elasticity of domestic use could be determined.

Based on their use of this equation, Howe and Linaweaver next concluded that domestic in-house use represented a demand relatively inelastic with respect to pricing changes.

Effect on summer sprinkling demands by pricing was considered as described by the following equation:

$$g = 3657 r^{0.309} p^{-0.93}$$

where $r = b(w - 0.6s)$

and p = price per 1000 gallons in cents
b = irrigable area in acres surrounding dwelling unit
w = average summer potential evapotranspiration in inches calculated by the Thornthwaite method about 10" in the eastern United States
s = summer precipitation in inches

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[1] Howe, Charles W. and Linaweaver, F. P. Jr., "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," Water Resources Research, III, No. 1 (1967).

[2] Linaweaver, F. P. Jr., Geyer, John C., and Wolff, Jerome B. A Study of Residential Water Use, Washington: Department of Housing and Urban Development, Report TS-12, February 1967.

From use of this equation, it was determined that the sprinkling demand was responsive to price change. The Howe and Linaweaver work indicated, then, that residential water demand is dependent on the price charged. Typical in-house demands exhibited a price elasticity of -0.23,[1] e.g., a 10% increase in price will reduce demand by 2.3%, while the price elasticity for sprinkling demands was 0.93. Sprinkling use is, therefore, more strongly affected by price change than domestic use. The authors felt that pricing could be used as an effective tool to decrease average day demands and increase revenue.

Because of the different industrial water use requirements and variations in plant process flexibility, a single elasticity coefficient for all industrial use is probably unattainable. Research in this field appears quite limited. One small scale study, however, has been undertaken within Massachusetts and the results of this study are described in the following paragraph.

Coefficients of elasticity for water demand response to pricing changes were studied by Stephen J. Turnovsky.[2] This study was primarily directed to the question of the response of individuals to an uncertain supply of water. From data collected from a sample of Massachusetts towns, the coefficient of elasticity derived for household use was around 0.3, and for industrial demand, about 0.5.

c) Application of Prior Study Conclusions to Eastern Massachusetts

As described in the previous paragraphs, both Howe-Linaweaver and Turnovsky have developed equations and price elasticity based on empirical data which suggest the influence which pricing may have on demand. In an attempt to determine the significance of these relationships to current water demand in eastern Massachusetts, a computer program using these relationships was developed for communities serviced by the MDC.

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[1] based on a house market value of $20,000 and cost of water at 40¢/1000 gallons.

[2] Turnovsky, Stephen J., "The Demand for Water: Some Empirical Evidence on Consumers Response to a Commodity Uncertain in Supply," Water Resources Research, V, No. 2 (April 1969).

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Once the computer program had been developed, a series of hypothetical price increases were imposed on the existing municipal rate structures. The effect of these increases on both domestic and in-house use and lawn sprinkling requirements are shown in the following table:

TABLE 19

Effect of Hypothetical Water Supply Rate Increases on MDC Demand.

Price Increase ¢/1000 gals	Theoretical Decrease			
	Domestic Demand	Lawn Sprinkling Demand	Industrial[1] Demand	Total
5	4.3	1.2	1.4	6.9
10	8.6	2.1	2.7	13.4
15	13.0	2.9	4.1	20.0
20	17.3	3.5	5.4	26.2
30	21.6	4.1	8.3	34.0
40	25.9	4.6	10.7	41.2
50	34.5	5.3	13.7	53.5

d) Discussion

As illustrated in Table 19, price adjustments would appear to offer an alternative to development of supplemental water supplies. Theoretically, a price increase of 50¢ per 1,000 gallons could be expected to reduce domestic or in-house demands by about 34 mgd and a corresponding decrease in lawn sprinkling demand by about 5 mgd. Industrial water use demands are indicated to react by decreasing almost 14 mgd. The total theoretical decrease on the system then with such a price increase would be about 53 mgd.

On the basis of the theoretical equations then pricing would appear to be a valuable tool for conservation of the water resource. A number of questions, however, arise concerning the direct application of these forecast decreased demands to the water supply situation at hand.

[1] does not include partially serviced communities

First, the empirical data used in the derivation of the domestic use equations, although the most extensive to date is far from all inclusive. Data used was derived from 21 areas nationwide, which contained about 5000 dwelling units. None of the test areas were located within Southeastern New England, although data available from the Middle Atlantic States was used.

In the analysis of industrial water demand reaction data utilized was quite limited, and other research in this area is almost non-existent. Development of any hard policy conclusions based on such sketchy information is, therefore, uncertain at best.

Second, the derivation of the empirical equations for domestic use was based on a "static" view of cost versus use. That is, the data employed was not an observation of a group of communities actual reaction to pricing changes. Rather the equations were developed by using a number of communities, which for a given point in time, had different water use with their individual rate structures. For example, Community A in 1970 used 100 gpcd at a cost of 20¢ per thousand gallons; Community B in the same year recorded an average use of 50 gpcd at a cost of 40¢ per thousand gallons. Based on the approach used by Howe and Linaweaver, the expected decrease in use from Community A with a price increase to 40¢/1000 gallons would be 50 gpcd. Whether the use of such a "static" scenerio to predict dynamic conditions is valid is unknown.

That the equations may not indeed reflect the dynamic situation which would occur with a price increase is particularly suspect with actual operating experience in the Boston Region. For example, in the Boston Region, the MDC increased wholesale prices for its water from $40 to $80 per million gallons in 1954, and $80 to the current $120 per million gallons in 1962. Neither of these price increases was accompanied by a decrease in per capita demand on the system, in fact, demand increased on the system.

To further evaluate the dynamic impact of pricing in an actual operating experience, a survey was made of a privately owned water company which recently applied a 24¢ per 1000 gallons to its water rates. This rate increase raised the cost of water to the consumer from $1.00 to $1.24 per 1000 gallons. The two communities serviced by the company are principally residential, thus the rate increase based on the empirical equation should be expected to result in a demand decrease or, in any event, a decrease in the rate of increase. The company reports,

were available from a study made by MAPC.[8] We applied these forecasts to individual communities in the following manner:

(5.1) $$G_i^t = \alpha_i G_{MA}^t \qquad \text{for } 1991 \leq t \leq 2020$$

where G_i^t expansion rate of the i^{th} community at time t

G_{MA}^t expansion rate of the Metropolitan Area at time t

(5.2) where $$\alpha_i = \frac{G_i^{1990}}{G_{MA}^{1990}}$$

or α_i is the last observed ratio (for the year 1990) of the expansion rate of the i^{th} community to the expansion rate of the area.

Thus, if a community expanded by a factor of 1.04 in 1990, and the whole area expanded by a factor of 1.02 during the same year, we forecasted that after 1990 the community would continue to expand with a factor equal to 1.02 (=1.04/1.02) times the expansion of the whole area.

4.4.2 Projection of Total Employment for the 66 Cities

We did not project employment directly, but rather the ratio of employment to population of each town. This ratio multiplied by population projections served as the projected employment for the 66 cities.

The ratio was projected in a two-stage manner--first for sample cities, and then for all receivers.

- Employment Projection for Sample Cities

For most of the sample cities a strong observed trend was visible in the ratio of employment to population during the 1960-1970 period. No forecasts were available for dates into the future except, again, for

[8] Metropolitan Area Planning Council: Economic Base and Population Study, Vol. I.

Natick and for the whole Metropolitan Area. The latter showed no significant trend.

The fact that the overall ratio of total employment to population in a region is relatively constant reflects nothing more than that the labor force participation of individuals is not significantly changing.

To extend this to all sample communities, however, would imply using the highly questionable assumption that cities will not become any more or less commercial in the future than they are now--an assumption clearly contrary to the observed trend of increased commercial activity in certain cities despite declining population and vice versa.

We chose instead to extrapolate the trend of the 1960's into the future for each sample city, using the method of decaying trends.

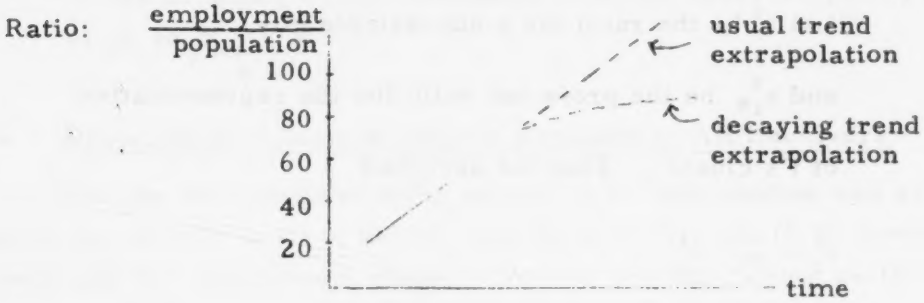

Figure 6.

In particular, we assumed that if the ratio grew at a rate of 40% from 1960-1970, it would grow at a lesser rate, 8% during 1970-1980, with still a smaller rate, say 1.6% during the next decade, etc. This says that

$$g_i^t = g_i^{1970} \cdot \alpha^{t-1970} \qquad (5.3)$$

where g_i^t is the growth rate of the ratio for the i^{th} community and α is an arbitrary constant we chose to set at 0.2.

Thus we projected the ratio of employment/population (call it r) using the g's projected by equation (5.3):

(5.4) $$r_i^t = r_i^{t-1} \cdot (1 + g_i^t)$$

Employment (E_i^t) in turn was projected by using the population projections (P_i^t) from the previous stage.

(5.5) $$E_i^t = r_i^t \cdot P_i^t$$

- Employment Projections Extended to All Receivers

Insofar as we were unable to obtain data needed to make the projections of Section 5.2.1 for all cities, we estimated the ratio of employment/population for each city from the projected magnitude of the coefficient for the representative city of the cluster.

Let r^t be the ratio for a non-sample city,

and r_{i*}^t be the projected ratio for the representative

of i's cluster. Then we assumed:

(5.6) $$r_i^t = \alpha \cdot r_{i*}^t$$

where $\alpha = r_i^{1970} / r_{i*}^{1970}$,

or, the constant α was estimated from the observed (1970) ratio of r_i to r_{i*}.

Having thus obtained employment/population ratios for <u>all</u> receivers, we could again use equation (5.5) to project employment for all receivers.

4.4 3 <u>Projection of Sectoral Employment for the 66 Cities</u>

Once again we resorted to a two-stage process for estimating the breakdowns of employment into the three sectors need for this analysis.

- **Projections of Sectoral Shares for Sample Cities**

Let the share of sector j in the total employment of community i be represented by ${}_jS_i^t$. The sector j has a general development trend obtained from the MAPC Study cited earlier; this is ${}_jS_{MA}^t$, or the share of sector j in the overall region's employment.

We assumed a constant relation between the share of the activity in a city, and the share of the activity in the Metropolitan Area, namely:

$$(5.7) \qquad {}_jS_i^t = \alpha_j {}_jS_{MA}^t$$

where $\alpha_j = {}_jS_i^{1970} / {}_{MA}S_i^{1970}$,

or the constant α was estimated from the observed (1970) ratio of ${}_jS_i$ to ${}_jS_{MA}$.

- **Projections of Sectoral Shares Extended to All Receivers**

For the non-manufacturing sector (j=3), information was available on the 66-city level of detail, and we used formula (5.7) directly to estimate the employment share of the non-manufacturing sector in all 66 communities.

For the share of manufacturing employment in each of the two manufacturing sectors considered in our study, we assumed (for lack of an alternative) that the two sectors exist in the very same proportion in all cities in the cluster, and thus set the share of manufacturing employment in each of the two manufacturing sectors equal to the projections for the sample communities:

$$(5.8) \qquad {}_jS_i^t = (1 - {}_3S_i^t) \frac{{}_jS_{i*}^t}{(1 - {}_3S_{i*}^t)} \qquad j = 1 \text{ and } 2$$

where the subscripts refer to:

j = 1 heavy water using manufacturing
j = 2 other manufacturing
j = 3 non-manufacturing.

Thus employment projections ($_jE_i^t$) for sector j at time t in city i could now be made for all receivers, using projections of section 5.2.2:

(5.9) $$_jE_i^t = {}_jS_i^t \cdot E_i^t$$

4.4.4 Value Added Projections for the 66 Cities

For each sector we projected value added per man by using (a) the 1963 Census Statistics, Massachusetts data, and (b) the MAPC projections of productivity increase over the 1963-2020 period:

(5.10) $$v_j^t = v_j^{1963} \cdot p_j^t$$

where v_j^t is value added per man at time t,

v_j^{1963} is obtained from census data,

p_j^t is a productivity index obtained from the previously cited MAPC study.

We must observe here that both the Census and the MAPC provided the information on v's and p's for a more detailed sectoral breakdown; this information was averaged (weighted by area employment for the time t) to yield v's and p's for our more aggregated sectoral classification.

Assuming that value added per man is the same for each city (given, of course, time and sector), so that the v_j^t's could now be applied to the sectoral employment projections of Section 5.3.2 to give sectoral value added projections for each city ($_jVA_i^t$):

(5.11) $$_jVA_i^t = v_j^t \cdot {}_jE_i^t .$$

4.5 Projections of Unconstrained Water Demand and Local Water Supply

While projections for water demand were available until 1990 for the system as a whole (supplied by the Corps) and for individual receivers (from the Camp, Dresser, and McKee study cited earlier), there was no projection available for either the system or the communities after 1990. Consequently we had to construct water demand projections for the period 1990-2020, and also local water supply projections for the communities studied in order to estimate demand for MDC supplied water.

4.5.1 Unconstrained Demand Projections

We assumed that the water demand (W_i^t) for city i at time t could be written as the sum of uses in the various activities projected for the city:

$$(6.1) \qquad W_i^t = {}_pC_i^t \cdot P_i^t + \sum_{j=1}^{3} {}_jC_i^t \cdot {}_jVA_i^t$$

where ${}_pC_i^t$ domestic consumption coefficient in i at t,

${}_jC_i^t$ consumption coefficient of j^{th} economic sector in i at time t.

Our task, then, was to project the coefficients (C's) and then compute water demand according to (6.1) using projections of VA and P. The strategy we followed was to obtain preliminary estimates of the C's, and then to calibrate these initial estimates so that they would in effect "explain" the projections we had for the 1970-1990 period from sources cited earlier. After 1990 the calibrated coefficients were allowed to "go on their own"; i.e. we derived W_i^t's directly from equation (6.1) for $t > 1990$.

- Initial Coefficient Estimates

The current (appr. 1970) coefficient estimates were determined as follows:

(1) The volume of domestic water consumption was collected for all sample cities by telephone interview with their respective water departments. This was divided by population to yield a per capita consumption coefficient.

(2) The Massachusetts water-use data from the 1963 Census of Manufactures was used to obtain water consumption estimates for the two manufacturing sectors.

(3) Non-manufacturing economic activity was assumed to have coefficients equal to the "other" manufacturing sector (i.e. manufacturing excluding heavy water users).

These current coefficients were projected into the future using data in another RFF study, Wollman and Bonem's national survey of water adequacy.[9] That study provides regional indices of water intake coefficients for economic sectors as well as for domestic consumption. Their New England estimates were used here.

These index numbers extend to 2020, and some interpolation was done to get index values for years not explicitly considered in their work. Our current coefficient estimates were projected into the future using the Wollman/Bonem indices to introduce changes over time.

- Calibration of Coefficients

We proceeded through three stages in calibrating the coefficients developed in Section 6.1.1. The first stage involved the proportional rescaling of the economic sectors' coefficients for each of the sample cities so that they would in fact yield total non-domestic water use.

[9] N. Wollman and G. W. Bonem: The Outlook for Water: Quality, Quantity, and Growth, Resources for the Future, 1971.

From the telephone survey cited above, we had non-domestic water use estimates for the sample cities for the year 1971. Coefficients for all future years were scaled in proportion to the scaling necessary to yield non-domestic use in 1971.[10]

After the first stage of calibration, the coefficients for the sample cities (now consistent with 1971 demand data) were assigned to all the other members of their respective clusters. We now went on to the second stage of calibration, and scaled each town's coefficients so that the total demand computed via equation (6.1) would equal the Camp, Dresser, and McKee projections for 1970-1990.

Yet a third stage of calibration was necessary because the Camp, Dresser, and McKee projections of MDC demand (i.e. total water demand less locally supplied water for the communities served by the MDC) did not fully agree with system demand as estimated by the Corps. We assumed that

(a) all potential receivers enter the MDC system between 1971 and 1976,

(b) the Corps' projections for system demand are correct, and

(c) the Camp, Dresser, and McKee projections of local supplies are correct.

According to these assumptions we scaled down all coefficients to yield a figure for total water demand (summed over receivers) which exceeds local water supplies (summed over receivers) by an amount equal to the Corps' projection of the demand for MDC water when all receivers are served.

Two observations are due here. First, the projections of demand were actually performed only for the years at the start of each decade (1970, 1980, 1990, etc.) and were interpolated for years within the decades. As a result, although our demand data (all receivers served) agree with the Corps' estimate for these benchmark years, our data do not exactly

[10] This stage of scaling did not need to be applied to the domestic coefficient, because that coefficient was in fact developed directly from the domestic water use data.

agree with the Corps' estimate for years within each decade.

Second, at the third stage of calibration we had a choice of alternatives in calibrating to achieve consistency with the Corps' system demand estimates: (a) all receivers are served, or (b) presently served members only are served. By calibrating according to option (a), we in fact destroyed the strict equality between our system demand projections and those of the Corps when no new communities are admitted the system.

There was, of course, no way of calibrating beyond 1990. Indeed, the whole exercise would have been unnecessary had we had demand data after that. In effect, our coefficients after 1990 are the fully calibrated coefficients for 1990 extrapolated until 2020 using the Wollman-Bonem indices of coefficient change.

4.5.2 Local Supply Projections

The Camp, Dresser, and McKee study provided estimates of available local water supply for each of the 66 receivers until 1990. For years after 1990, we used the "decaying trend" method of estimating local supplies. (See Section 5.2.1.) This means, in effect, that if a community's local yield is declining in the 1980-1990 decade, we assumed that it would continue to decline thereafter, though at a decreasing rate.

This may mean that we have seriously underestimated local supply sources, especially if we expect the wastewater quality to improve in the area. The reason for this is that the Camp, Dresser, and McKee study bases its local supply changes on the assumption that MDC water will be readily available. We suspect that often the decline in local yield is not due to conditions of the source, but rather due to the convenience or profitability of buying water from the MDC itself.

Accordingly, we feel that the Corps', and thus necessarily our, estimate of MDC demand may be overstated by as much as 10-30% if conditions make it sensible to keep local sources operating at their technical capacity.

The projected local supplies are presented in Table 11.

Table 11. LOCAL WATER SUPPLY PROJECTIONS (MGD)

	COMMUNITY	1970	1980	1990	2000	2010	2020
1	ARLING	-0.00	-0.00	0.0	0.0	0.0	0.0
2	BELMON	-0.00	-0.00	0.0	0.0	0.0	0.0
3	BOSTON	-0.00	-0.00	0.0	0.0	0.0	0.0
4	BRKLNE	-0.00	-0.00	0.0	0.0	0.0	0.0
5	CHLSEA	-0.00	-0.00	0.0	0.0	0.0	0.0
6	EVERET	-0.00	-0.00	0.0	0.0	0.0	0.0
7	LEXING	-0.00	-0.00	0.0	0.0	0.0	0.0
8	LYNFLD	0.0	0.0	0.0	0.0	0.0	0.0
9	MALDEN	-0.00	-0.00	0.0	0.0	0.0	0.0
10	MRBLHD	-0.00	-0.00	0.0	0.0	0.0	0.0
11	MEDFRD	-0.00	-0.00	0.0	0.0	0.0	0.0
12	MELROS	-0.00	-0.00	0.0	0.0	0.0	0.0
13	MILTON	-0.00	-0.00	0.0	0.0	0.0	0.0
14	NAHANT	-0.00	-0.00	0.0	0.0	0.0	0.0
15	NEWTON	-0.00	-0.00	0.0	0.0	0.0	0.0
16	NORWOD	-0.00	-0.00	0.0	0.0	0.0	0.0
17	QUINCY	-0.00	-0.00	0.0	0.0	0.0	0.0
18	REVERE	-0.00	-0.00	0.0	0.0	0.0	0.0
19	SAUGUS	-0.00	-0.00	0.0	0.0	0.0	0.0
20	SMRVLE	-0.00	-0.00	0.0	0.0	0.0	0.0
21	STNHAM	-0.00	-0.00	0.0	0.0	0.0	0.0
22	SWPSCT	-0.00	-0.00	0.0	0.0	0.0	0.0
23	WALTHM	-0.00	-0.00	0.0	0.0	0.0	0.0
24	WATER	-0.00	-0.00	0.0	0.0	0.0	0.0
25	WNTHRP	-0.00	-0.00	0.0	0.0	0.0	0.0
26	CAMBRG	13.61	13.75	13.70	13.69	13.69	13.69
27	CANTON	2.99	2.96	3.00	3.01	3.01	3.01
28	NEDHAM	2.50	2.92	3.40	3.51	3.54	3.54
29	PABODY	3.11	3.24	3.10	3.07	3.07	3.07
30	WAKFLD	0.98	1.01	1.00	1.00	1.00	1.00
31	WESTON	0.77	1.29	2.10	2.37	2.43	2.44
32	WNCHTR	0.81	0.78	0.70	0.69	0.68	0.68
33	CLNTON	-0.00	-0.00	0.0	0.0	0.0	0.0
34	CHICOP	-0.00	-0.00	0.0	0.0	0.0	0.0
35	FRMGHM	2.07	2.12	2.10	2.10	2.10	2.10
36	LNCAST	0.41	0.61	0.90	0.99	1.00	1.01
37	LECMIN	5.77	6.03	6.30	6.36	6.37	6.37
38	MRBOGH	1.54	1.64	1.60	1.59	1.59	1.59
39	NTHBOR	0.55	0.87	1.20	1.29	1.31	1.32
40	STHBRH	-0.00	-0.00	0.0	0.0	0.0	0.0
41	STHHAD	-0.00	-0.00	0.0	0.0	0.0	0.0
42	WILBRA	-0.00	-0.00	0.0	0.0	0.0	0.0
43	ASHLAN	0.84	0.13	0.20	0.22	0.23	0.23
44	AVON	0.48	0.50	0.80	0.89	0.92	0.92
45	BOLTON	1.36	0.74	0.40	0.36	0.36	0.36
46	BRNTRE	4.02	3.08	3.00	2.98	2.98	2.98
47	CEDHAM	2.95	3.24	3.10	3.07	3.07	3.07

COMMUNITY	1970	1980	1990	2000	2010	2020
48 DOVER	0.24	-0.00	0.0	0.0	0.0	0.0
49 HCLBRK	1.01	1.42	2.00	2.16	2.20	2.20
50 HCLSTN	0.59	0.11	0.10	0.10	0.10	0.10
51 HUDSON	1.34	1.17	1.10	1.09	1.08	1.08
52 LINCON	0.66	0.61	0.90	0.99	1.01	1.01
53 MAYNRD	0.66	-0.00	0.0	0.0	0.0	0.0
54 MEDFLD	0.73	0.93	1.10	1.14	1.15	1.15
55 MILLIS	0.42	0.13	0.20	0.22	0.23	0.23
56 NATICK	6.74	5.02	5.50	5.60	5.63	5.63
57 NORFOK	0.04	0.10	0.70	1.52	1.87	1.96
58 RANDLP	2.15	3.14	4.60	5.03	5.12	5.14
59 SHRBRN	0.12	0.33	0.90	1.21	1.29	1.31
60 STCTON	2.64	2.39	3.00	3.19	3.19	3.19
[illegible]	1.1[illegible]	0.6[illegible]	0.0	0.0	0.0	0.0
62 SUDBRY	0.61	0.13	0.20	0.22	0.22	0.22
63 WELSLY	3.71	3.[illegible]	3.30	3.21	3.20	3.19
64 WSTWOD	1.02	-0.00	0.0	0.0	0.0	0.0
65 WEYMTH	4.24	4.58	4.30	4.25	4.24	4.24
66 WOBURN	5.69	4.47	5.30	5.50	5.54	5.55

4.6 Projection of Realized Activity Base: Simulation Model

The overall demand for MDC water is obviously the sum of the individual demands of served communities. In attempting to simulate the response of MDC receivers to an inadequacy of MDC supply sources, we have to consider the precise implications of MDC restrictions on each individual community.

In particular, a 30% restriction on MDC purchases implies a 30% restriction on a particular town's demand only if:

(a) the MDC applies restrictions uniformly to each community's demand for MDC water, and

(b) the town has no local sources of water.

The first condition, (a), we have assumed throughout this study--restrictions apply uniformly for all towns served. We may observe here that this is not a fair way of rationing whatever water is available, for towns which depend entirely on the MDC suffer more than those communities which have local sources of their own. The second condition, (b), we have clearly not taken for granted, and in the present section we show how the towns' local sources determined the amount by which the towns' supplies had to be restricted in face of restrictions by the MDC.

Our computer model started the search for the equilibrium MDC restriction (in a given year) with the restriction rate that would have obtained had the unconstrained trend been realized. At this MDC restriction level the model then computed what the local restriction rate would have been for each of the 66 cities had their unconstrained activity trend been realized. For example, if a city relied on the MDC for 30% of its water, and the MDC applied a 10% restriction on all of its clients, the city's actual shortage would have been 3%.

At this point, the model simulated the response of the various activities in each city to the local restriction, computing how far below the unconstrained trend the city's activities would drop at the trial restriction rate. By using the water demand equations in Section 4.5.1

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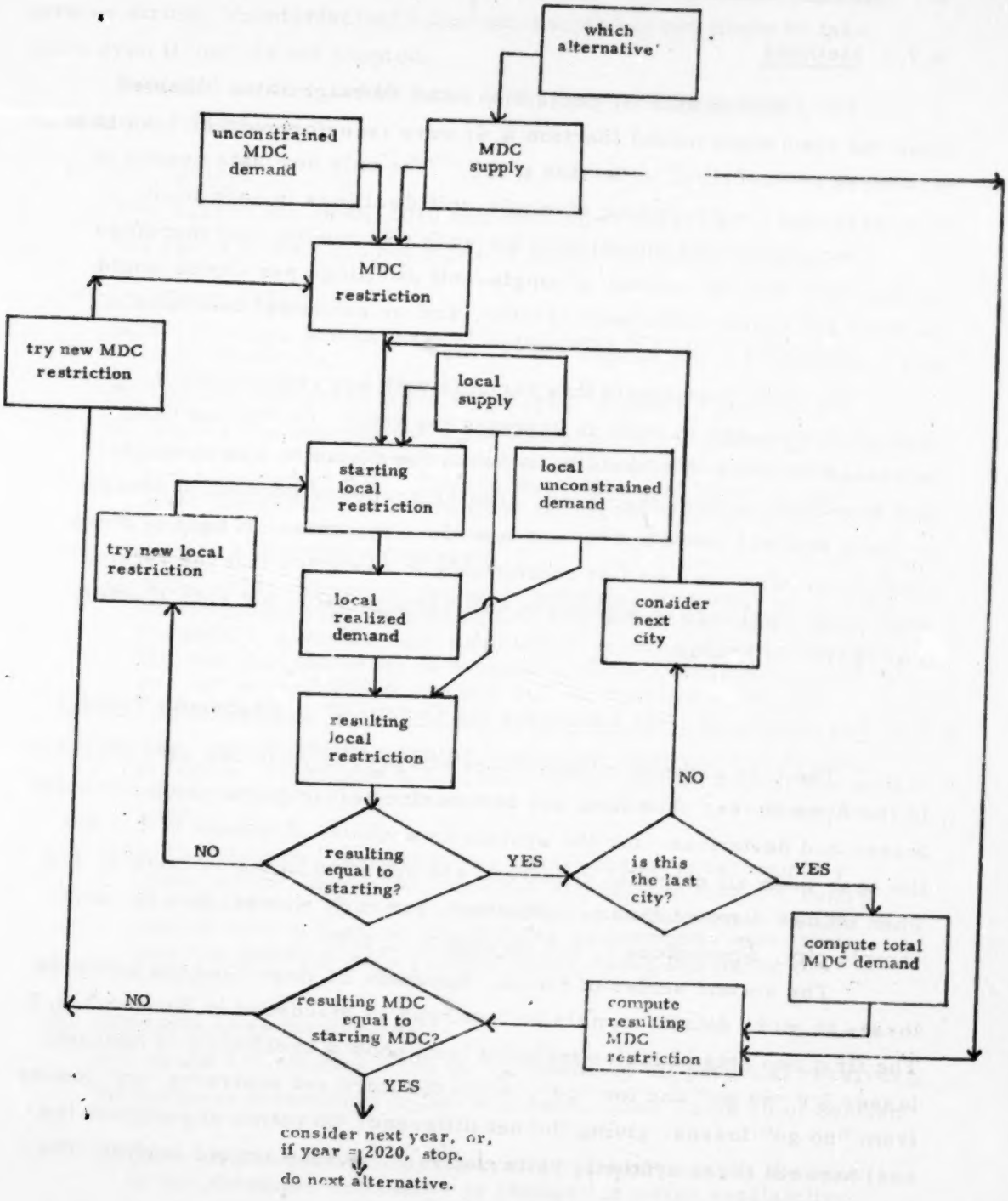
the model computed the new demand, computed the restriction implied by the new demand, and checked it against the trial rate used to start the analysis. If the starting and resulting rates were close (within 2%), the analysis ended, yielding an equilibrium value for the local restriction rate, and for the local demand for water. If the starting and resulting rates were not close, a new iteration was made with a restriction half-way between the starting and resulting magnitudes of the previous round.

After finding an equilibrium for each city, the model summed the demand for MDC water from all served cities, and computed the restriction on MDC water that would have resulted. Once again, if the starting and resulting rates were far apart, a new rate was tried. Only when the starting and resulting values were close (differed by less than 5% of the starting value) was the problem considered solved.

After thus finding an equilibrium for the system as a whole, as well as for each individual community, the model moved on to consider the next year in the analysis. The supply for the next year was determined by adding the yield of the system (which depended, of course, on whether the "go" or the "no go" alternative was studied) to however much was available in stocks. In each period, care was taken to adjust the stocks by the amount of withdrawals (or additions) that took place during the period.

The model is illustrated by the flow chart in Figure 7. It is important to remember here that temporary shortages induced by a drought were not allowed to cause demand adjustments; the demand fell below unconstrained demand only as a consequence of permanent restrictions.

Figure 7. Simulation Model



4.7 Loss Computations and Analysis

4.7.1 Methods

The realized activity projections and shortage rates obtained from the simulation model (Section 4.6) were transformed into loss base measures as described in Section 4.3.2. The only new data needed at this stage was the projection of single-unit dwellings in each town.

Such data were unavailable for each community, and therefore we assumed that the number of single-unit dwellings per capita would be equal for cities within each cluster, and we estimated the value of this coefficient for the sample cities only.

We could not project this variable with any real certainty; opposite trends are at work in changing the ratio. On the one hand, increased incomes are likely to increase the desire to live in single-unit dwellings; on the other hand, greater predicted population density is likely to force more apartment-type developments. In light of these conflicting influences we felt comfortable in assuming that the ratio of single-unit dwellings to population will remain stable for each cluster; i.e. at its 1970 value.

4.7.2 Description of Loss Estimates for Communities (Appendix Tables)

The loss estimates themselves are presented in two sets of tables in the Appendices. The first set summarizes all impacts--both concrete losses and deviations--for the system as a whole: Appendix I, 1.1 for the case when all potential receivers are admitted to the system, I, 1.2 when no new communities are admitted, for each cluster, and for each sample city, Appendices I, 2.1 through I, 2.1.2.

The second series of tables, Appendix II, describes the concrete losses in more detail, namely by loss type as discussed in Section 3.2.3. The first two sets of tables included here show a breakdown of concrete losses for "no go" and for "go", while the third set subtracts "go" losses from "no go" losses, giving the net difference (in terms of concrete losses) between these synthetic "alternatives". As we argued earlier, the

'no go" situation is something less than an alternative, since it incorporates strong, counterfactual assumptions, and is not likely to take place even if "go" is not adopted.

Attention is directed to some of the less obvious aspects of these tabular displays.

(1) All Tables:

The figures for 2000, 2010 and 2020 show losses in those calendar years alone, and not sums of losses for those decades.

(2) Summary Tables:

(a) All $ values are expressed in millions $1963. Population is in thousands.

(b) The unconstrained trend is marked "Enough Supply".

(c) Losses are counted from the viewpoint of all potential receivers, regardless of whether all potential receivers are admitted or not. Thus in the tables that show losses when the service is assumed to be provided to presently served cities only, we see a sum of the losses of cities served and cities not served.

(d) When MDC service is denied to potential receivers (i. e. only communities already served are allowed to buy water from the MDC), even the "go" alternative creates losses. Despite the fact that the water is available, those communities who are not in the MDC at present will be exposed to serious restrictions.

(e) The "go" alternative begins to become inadequate according to Table 7 of Section 4. 2. 5; this can be seen in any of the tables pertaining to sample cities that are presently served by the MDC.

(f) In the "drought" situation, we assumed that local supplies would not fall below their normal yields, and that the Tully-Northfield part of the system would not fall below 120 mgd. (See Section 4. 2. 2). In effect, these assumptions mean that only the existing MDC system yields would fall under the drought.

(3) Concrete Loss Summaries:

(a) Losses are counted from the viewpoint of all potential receivers.

(b) Business investment losses are zero. (See Table 10 of Section 4. 3. 2.)

(c) Domestic investment losses are not proportional to the size of the shortage, but rather to changes in water availability.

Thus a large part of such investments are made when the shortages first appear. New wells are dug when restrictions are applied and maintained. Once a well has been dug to adjust to a given level of restrictions, it need not be dug again unless higher restrictions are imposed. (See Section 4.3.2)

(d) In the domestic investment category the "no go" alternative implies lower losses for some years than the "go" alternative. This happens because in the "no go" case shortages arrive only at a fairly late date, and by that time people will have made their domestic investments under "no go".

(e) City revenue losses are clearly the largest item in the concrete loss category.

(f) In terms of concrete losses, the "go" alternative is most profitable relative to "no go" in the years 1990-2010. (See Section 4.2.5.)

4.7.3 Losses for the System (Excluding Losses by Communities)

We come now to the last set of impact estimates: those pertaining to the system as a whole. Two categories are involved here: (a) revenue lost by the MDC from not being able to sell water to meet unconstrained demand, and (b) gains derived from not having to renovate the unavailable water.

- Revenue Lost to the MDC

The average price of water to the member communities was determined from our telephone interview with the sample towns' water departments. We estimated that the MDC charges approximately $43,700 per mgd per year. The loss estimate is simply this figure times the mgd difference between sales and unconstrained demand.

- Gains in Reduced Water Treatment Costs

There are two reasons for including this item in the present computations. First, the system would probably realize concrete gains from not having to clean the additional water, though these gains are not likely to be as large as the ones we show in Table 12.

Table 12, Losses for the System* ($1971 Mill)

	SERVICE: ALL RECEIVERS				SERVICE: NON-SERVED ONLY			
	Lost Revenue, MDC		Avoided Treatment**		Lost Revenue, MDC		Avoided Treatment**	
	No Go	Go	No Go	Go	No Go	Go	No Go	Go
1976	0.	0.	0.	0.	0.	0.	0.	0.
1977	0.	0.	0.	0.	0.	0.	0.	0.
1978	0.	0.	0.	0.	0.	0.	0.	0.
1979	0.	0.	0.	0.	0.	0.	0.	0.
1980	0.	0.	0.	0.	0.	0.	0.	0.
1981	0.	0.	0.	0.	0.	0.	0.	0.
1982	2.928	0.	-4.502	0.	0.	0.	0.	0.
1983	3.278	0.	-5.040	0.	0.	0.	0.	0.
1984	3.627	0.	-5.578	0.	2.535	0.	-3.898	0.
1985	3.977	0.	-6.115	0.	2.841	0.	-4.368	0.
1986	4.370	0.	-6.720	0.	3.103	0.	-4.771	0.
1987	4.720	0.	-7.258	0.	3.409	0.	-5.242	0.
1988	5.069	0.	-7.795	0.	3.671	0.	-5.645	0.
1989	5.419	0.	-8.333	0.	3.933	0.	-6.048	0.
1990	5.768	0.	-8.870	0.	4.239	0.	-6.518	0.
2000	9.090	0.	-13.978	0.	6.599	0.	-10.147	0.
2010	13.329	8.085	-20.496	-12.432	9.369	0.	-14.448	0.
2020	18.573	13.329	-28.560	-20.496	12.673	7.429	-19.488	-7.429

* Negative losses are gains; see Section 8.3.2.

** Assuming eventual treatment of 100% of the delivered water. For non-zero consumption loss rates these figures must be adjusted by a factor of 0.7.

The second reason is that the environmental damage caused by using the extra water has to be accounted for in some fashion. The natural price to put on what it costs to use clean water is the cost of cleaning it, or the amount of money it takes to return it in its original form.[11] This is an externality or cost incurred by society, yet not included in the price of a good. The environmental damage caused by using clean water and not returning it to the environment in its clear form involves such costs. If treatment is in fact undertaken, then the costs of treatment are usually external costs, i.e. not included in the price of the good used, in this case water.

However, external costs must not be neglected by competitive markets as they have been if environmental quality is to be an achievable goal. Therefore, in this analysis, we take into account external costs by imputing the value of the environmental damage that we prevent by sustaining water shortages.

But what level of cleanliness should we count as the proxy for damage prevented?[12] No feasible technique we have so far devised can totally reverse the damage caused by domestic, and especially industrial water use. But for the purposes of the present study we nevertheless have to pinpoint a magnitude. We chose the cost of a level of treatment, which, given current economic and technical feasibilities, does provide high water quality: tertiary treatment. This, indeed, is the system proposed by the Corps and others for the seriously degraded waters of New England's Merrimack. The cost estimate used comes from an Arthur D. Little study[13], and puts the cost (assuming 30% industrial waste) at 18.4¢ per 1000 gallons, or at roughly $67,200 per mgd per year.

These gains are shown alongside the revenue losses of the system as a whole in Table 12. It is important to note that the avoided

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[11] If X spills coffee on Y's suit, the value of the damage they are likely to agree on is the cost of having Y's suit cleaned.

[12] Had X spilled ink instead of coffee on Y's suit, Y could well claim that the costs of cleaning would be very large, far beyond the normal costs of cleaning suits, and possibly that his suit might never be as good as it was.

[13] Arthur D. Little, Inc.: Fostering Industrial Growth in Massachusetts, Vol. II, 1971, p. 115.

treatment gains (a) are based on treatment rates above those presently observed in the MDC area, and (b) these gains will not accrue to the MDC, insofar as (i) some of the treatment would be avoided by the several localities, and (ii) ultimately not the MDC, but rather the taxpayers (industrial and individuals) would be realizing the savings from lower sewage treatment expenditures.

4.7.4 Revised "GO, Drought" Estimates and Their Effects

In the computations explained and presented in this report it was assumed that the Tully-Northfield components of the system would not themselves suffer lower yields during the hypothetical drought considered in our analysis. New data received from the Corps is now available to replace this unrealistic assumption, but unfortunately computations have already been completed.

Rather than recompute the model, an impossibility given limitations in time and resources, we will briefly explore the likely effects of this new data on the results presented. The new yields of Tully-Northfield under "drought" are shown in Table 13. They also result in new "GO" yields under drought, as shown in Table 5.

No revision in population and value added losses are implied by these modifications, since temporary shortages are assumed to leave these variables unaffected. The results are felt by concrete losses in two of the scenarios studied:

(a) GO, drought, all receivers served

(b) GO, drought, only present members served.

For "GO all served, drought" the following changes are likely to take place:

(1) Restrictions of 12.3% and 35.6% will have to be observed in 1979 and 1980, respectively. In the original computations both of these years showed zero restrictions.

(2) The system will run out of stocks about a year earlier than projected, i.e. in approximately 1995 instead of 1996. (See Table 7.)

(3) The concrete losses associated with the restrictions suffered in 1979 will be roughly similar to the concrete losses that

the No Go, all Served system shows for normal conditions in 1982.

(4) The concrete losses associated with the restrictions in 1980, will be roughly twice the No Go, all served, normal concrete losses in 1983.

For "Go, present served only, drought" the following changes are likely to take place:

(1) Restrictions of 28.2% will need to be observed in 1980, as opposed to zero in the original computations.

(2) The system stocks will be exhausted about 2 years earlier, in approximately 2007 instead of 2009. (See Table 7.)

(3) The concrete losses associated with the restrictions can be roughly computed as:

$$\text{Losses} \approx 2 \times \{\text{No Go, Present Served, Normal, 1984} - \text{No Go, Present Served, Normal, 1983}\}$$

This can then be added on to the GO, present served, drought losses shown in the old computations (resulting there from the exclusion of certain communities rather than from restrictions).

Table 13. Revised Yields of the Tully-Northfield Projects

	Yield (mgd)
Before 1976	120
76	104
77	88
78	103
79	31
80	90
After 1980	120

4.8 Qualitative Impact Data

From the statistical standpoint, the loss results obtained by the methods described in the previous sections appear to be reliable. Again, cluster totals enjoy a higher level of confidence than representative community losses, and system totals are still more accurate than cluster results. However, to give the data added credibility, we also examined the experience of an actual community already beset by the kinds of problems anticipated in the event of prolonged water shortage. Principally, "soft data" related to social impacts were our objective. How does a community respond to the dislocations of water use restrictions? Do citizens get more involved in planning when crisis conditions are sustained over a long period? How quickly does population growth slow in response to water-use and building restrictions? An extended interview with Stoughton's Planning Board Chairman produced both background and impact information (keyed by letter to impact categories displayed in Table 3, Impacts on Receiver Areas).

Stoughton is an industrial - residential community in the Brockton S. M. S. A. The town's population of about 25,000 is growing at a rate of more than 40% every decade, and shows no signs of a downward turn. The principal constraint on continuing growth may be an acute shortage of water. Presently municipal supplies come from five town wells; two recently completed standpipes with capacities of 10 and 2 million gallons give Stoughton about 14 million gallons of total storage. The severity of ongoing shortages are indicated by a complete ban on outside watering in effect for several years and a one-year freeze on the issuance of building permits lifted last year.

The town has been searching for water since 1955. First, an extensive drilling campaign at producing well sites was tried. When the results were disappointing, consulting engineers were engaged to search for new groundwater sources; results, negative or unacceptable because of high iron content. Last year a grant of $1.5 million funded a project to clean or replace defective distribution piping. In addition,

$150,000 was spent on a connection with Brockton and Canton water supplies. This, however, is seen as only a stop-gap measure because the doner towns can terminate the arrangement at will, whenever their capacities are strained. In general, admission to the M. D. C. system is viewed as the only permanent solution. Formal application has been made, but even favorable action means a delay of 8-10 years before Quabbin-Wachusett water becomes available.

The consequences of water deprivation have been felt across a wide range of community activities:

(A) 4.8.1 Land Use

Although no shifts in the allocations of land use type have occurred, development in the industrial category has been nearly stopped by water shortage. Interestingly, though a building ban prevented "new starts" on residential housing for a year, the rush to develop after the ban was lifted has more than wiped out any deficit.

(B) 4.8.2 Population

While our data projections for longer terms show population deficits for deviations from the "enough supply" situation, it does not appear that population growth is sensitive to short-term controls and constraints. Stoughton's in-migration continued despite the building ban and shows signs of growing even more quickly now that new housing construction has begun again.

(C) 4.8.3 Municipal Finance

Because finding water has been a top town priority, other municipal services have suffered. A sidewalk program has been indefinitely postponed and only minimal roadway maintenance and construction has occurred. Generally, expenditures have been cut as revenues from expected property taxation have dwindled. Estimates range as high as $1,000,000 in tax-loses with increases in assessments covering the deficit. The cost of water has doubled in the past two

years and the municipal debt as of January 1, 1970 stood at $7,516,000 or $320 per capita. Until a mutual help agreement was reached with Easton and Sharon, adequate fire protection was a critical concern.

(D) 4.8.4 Commercial Activity

In the time observed by the interviewee, there have been no perceptible consequences for either retail or wholesale trade.

(E) 4.8.5 Housing

Since the lifting of the building ban, over 500 rental units have been built and occupied. The demand for housing has lowered the vacancy rates significantly and stimulated the construction of 3,000 apartment units and the planned development of 3,000 more. Before the ban went into effect, issuances of building permits had declined an average of about 130 units per year for two successive years.

(F) 4.8.6 Education

Two primary schools of twenty-six classrooms each have been completed in the past two years (September 1970 and 1971) to accommodate a swelling elementary-age school population. A much-needed junior high has been put off - an effect attributed to the " extraordinarily high expenditures of finding water. " As a result, the present junior high is expected to go into double sessions this coming fall.

(G) 4.8.7 Security

As the search for water has become "business as usual", citizens appear to have developed some tolerances for the inconvenience of watering bans. However, their latent insecurity about adequate supplies for fire protection and general domestic consumption have made water shortage a perennial political issue on which concern can focus. As noted above, the prevailing attitude is that "everything will be all right" once M.D.C. admission is secured and the burden

of water planning can be shifted to the Commission.

(H) 4.8.8 Community Image

Despite the general slowdown in industrial development and its second order consequences on town revenues, the average citizen perceives the water supply problem in terms of his own inability to water outdoors. Lawns and shrubbery are a waste of money, says the homeowner, and the town looks poorer for it. A general feeling of discouragement and frustration has set in and the desirability of Stoughton as a residential community has been adversely affected. So far no monetary reflections of this malaise have developed and property values are as yet unchanged by water shortage.

(I) 4.8.9 Economic Stability

Economic development has been hurt because water using industries have been turned away. This has "slightly decreased" the stability of the town because the tax base has not expanded quickly enough to keep up with demands on local revenues. Wages and prices have remained in phase with the rest of the state, but taxes have increased.

(J) 4.8.10 Industrial Activity

No Stoughton industries have left because of water shortage, but new industries (chemical plant, refinery) have gone elsewhere. Presently only non-manufacturing, non-processing firms are permitted to locate in town, and a $40 million industrial park is now two years behind in its development schedule.

From the Stoughton example, we venture to say that public participation in the water resources decision process has been only episodic and then motivated by personal fears of impending shortage. The planning responsibility, the effective and efficient operation of water systems has been left to local, state and regional water administrators. Unfortunately, however, such specialization leads to sub-

optimization and the entrenchment of philosophies and procedures in the professional water manager that make him unresponsive to changing public attitudes.[14] In fact, his very security is the confidence he inspires in the public. For though it is supremely unconcerned when supply and distribution are proceeding normally, the public becomes vengeful when the tap runs dry. Thus, certainty, predictability, minimized risk, and conservatism are the hallmarks of the prudent water purveyor.

As a result, one consequence of implementing Tully and Northfield will be the perpetuation of the tyranny that an apathetic public exercises over its water managers. Receivers will not be forced to reexamine the basic questions underlying further efforts to increase the yield of Quabbin:

- Can exponential increases in urban water consumption, domestic and industrial, be controlled?
- Do other technical alternatives such as wastewater renovation offer multiple economic returns on a larger capital investment?
- Can the assumption of some known degree of risk by system managers increase economic efficiency and stimulate water husbandry?
- Should pricing policy be reformed to a) rationalize now widely divergent wholesale water prices throughout the system, and b) reflect more accurately the market value of the next unit of water to the consumer rather than to the middle-man town distributor?
- Would water distribution strategies halt urban agglomeration in the metropolitan area and stimulate growth elsewhere?
- Can an overhaul of existing M. D. C. administrative policies broaden the scope of its responsibility and political accountability? Can true regionalism -- not just systematization of a specific agency function -- be considered a realistic option?

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14 For a good treatment of the more obvious deficiencies in a system of unalloyed professionalism, see David J. Allee, "Efficient Management Policies for Urban Water Supply," Cornell Agricultural Economics Staff Paper, October 1970.

If planners wish to cope in a normative way with urban congestion and foster healthy interdependence among the Commonwealth's cities and towns, it appears to us that the water supply issue is an excellent vehicle for progress. The self-fulfilling prophecies of swelling demand and dwindling supply need not be repeated if receivers begin to participate in planning the facilities that serve them.

Of course, more immediate and pedestrian impacts on receivers can be foreseen for the "go" condition. Once the diversion water is made available, it will be of undiminished quality and place no markedly higher cost burden on consumers.[15] More importantly, community growth associated with the kinds of industrial and commercial activities analyzed above continue uninterrupted. Schools, hospitals, shopping centers, etc., and the social interactions they offer will not be affected by water use restrictions. Indeed, and perhaps most significantly, individual and corporate behavioral patterns will remain unchanged. Barring natural catastrophe, the per capita consumption of water will rise and only industries with an economic incentive to reduce water use will strive to limit total intake by recycling. Suburban development among present and potential members will not be impeded by water scarcity (although other factors might well cause construction slowdowns), and the second-generation transportation and employment effects associated with metropolitan sprawl will be repeated. Generally, water users will experience no interruptions in service and take little note of their good fortune. Especially, it is unlikely that receivers will associate continuing supplies with the Tully and Northfield Projects specifically. The source of supply will be irrelevant.

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[15] The cost-sharing arrangements for the Tully and Northfield complexes have not yet been worked out, and that fact by itself confuses the issue of impacts. Whereas substantial price hikes for M. D. C. water are considered essential by many, elimination of the welter of "equity" arrangements now governing M. D. C. - receiver relationships may prove politically infeasible.

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5.0 The Millers River Alternative

Having considered the Tully-Northfield plans in some detail, we believe that at best a cursory examination of yet another approach would be productive. As noted earlier, the absence of a "real" technical alternative (as opposed to the synthetic "no go") posed some serious methodological problems. More important, though, the attitude of the supplier area toward upstream diversions at Tarbell and Priest Brooks is sufficiently negative to make a search for mutually agreeable compromises worthwhile.

One particularly promising modification of the existing plans for the Millers Basin would be to incorporate renovated water as a potential diversion source.[1] This opens the option of freshet diversions directly from the Millers main stem and eliminates the need for one or more of the projects on the Miller tributaries. Significantly, spokesmen for supplier interests have more than once pointed to the polluted Millers as a problem beyond their own capabilities to solve. We believe there is the germ of a bargain in their predicament. Should the Corps be prepared to consider taking water at or near Athol and abandon plans for, say Tarbell and Priest Brooks, they would not only be providing the same volumes of water to replenish Quabbin as the original scheme, but they would also give the supplier area the advanced water treatment it might otherwise wait years to finance.

The outline of such a plan might be as follows:

1. Speeded implementation of secondary treatment plant construction to handle the major point source waste flows above Athol.
2. Corps-financed construction of advanced water treatment

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1 Arguments that water quality management by receivers is the better answer are complicated by two factors: (1) the Corps is unlikely to exercise its authority to recommend such a course of action, and (2) while the M. D. C. does have authority to construct some sewage treatment works, it does not by itself have the manpower or financial resources to undertake such a program among all its members.

facilities at the same plant sites to bring effluents up to fully renovated levels.

3. Diversion works construction across the Millers above Athol.
4. Tunnel or conduit connections from the Millers diversion site to the tunnel feeding Quabbin.
5. Implementation of the West Branch Tully portion of the present Tully Complex plan to provide an additional or backup diversion capability.

In addition to these structural elements, an agreement between supplier towns and the M. D. C. to provide the former with service connections would quiet fears about future need.

Although no clearly articulated engineering plans are yet available, significant impacts for the Millers plan can be discussed in general terms.

5.1 Land Use

The acreage requirements for plan implementation would be on the order of 100 acres; 36 at the West Branch site in Orange and about 60 acres in Athol. This represents fully 1,000 acres less than the takings necessary for the whole Tully Complex. Diversion works would be located nearer to population centers, however, and some care should be exercised to consider aesthetics in design. Upland reservoirs would be avoided, and no intrusion on Royalston or Winchendon open space would occur. One factor to be considered in this alternative is the incentive to rivershore development that a clean Millers would provide. Strong zoning or other land use controls may well be necessary to realize the full potential of water access.

5.2 Municipal Finance

If the Corps underwrites the expense of tertiary treatment, these costs must be reckoned as savings for the towns who would otherwise have to bear a portion of such expenses. Particularly since advanced treatment would not likely be considered for some years,

the cost savings for construction begun in the near future may be estimated as roughly 12% per year according to present rises in the construction cost index.

5.3 Leisure Opportunities

A clean Millers River could open up important new recreational boating or body contact opportunities unless access restrictions limit such uses. It is not now known whether sound sanitary practices would permit public access, but the potential should be evaluated.

5.4 Community Image

Not the least attractive aspect of the Millers plan would be a revitalization of the supplier area's self-image. Troubled by a stagnant economy and the oppressive presence of a seriously polluted river, the immediate Athol area could draw new strength from the knowledge that "things are really happening." The chemistry of a town's spirit is difficult to predict, but it is a safe guess that its status as a water cleanup showplace would do the area no harm. This factor contrasted with the bristling hostility generated by the Tully Complex plan is a compelling argument for more detailed consideration of the Millers alternative.

5.5 Economic Stability

It should be pointed out that the simultaneous construction of several treatment facilities and then the diversion structure itself would be likely to stimulate larger and more diversified effects on the regional economy than the present project. The tunneling and concreting labor required for the Tully plan would remain unchanged, but the additional need for sophisticated treatment equipment and surface construction labor may well produce larger value-added totals over project life.

Impacts on receivers, it should be noted, are essentially the same for the Millers alternative as the Tully Complex because the volume of water supplied is the same. Whatever differences might exist relate chiefly to the need for treatment equipment and professional services vended by receiver area companies.

IDENTIFICATION AND ASSESSMENT OF SOCIAL AND ECONOMIC IMPACTS

APPENDICES

Connecticut and Millers River Basin Diversions

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8	0.115	0.055	0.105	0.125	0.129	0.131	0.138	0.146	0.163	0.153	0.165	0.164	0.188	0.151	0.166	0.270	0.358	0.471

APPENDIX I. 1.1: SUMMARY OF LOSSES
UNIT:ALL RECEIVERS
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGC	NORMAL GC	DRAUGHT NCGO	DRAUGHT GO	POPULATION NCGC	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGC	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	2611.6	2611.6	2611.6	9492.1	9492.1	9492.1
1977	0.0	0.0	0.0	0.0	2628.6	2628.6	2628.6	9822.7	9822.7	9822.7
1978	0.0	0.0	14.698	0.0	2645.6	2645.6	2645.6	10153.3	10153.3	10153.3
1979	0.0	0.0	56.074	0.0	2662.6	2662.6	2662.6	10483.9	10483.9	10483.9
1980	0.0	0.0	14.935	0.0	2679.7	2679.7	2679.7	10814.4	10814.4	10814.4
1981	0.0	0.0	3.983	0.0	2701.0	2701.0	2701.0	11211.3	11211.3	11211.3
1982	6.291	0.0	4.441	0.0	2682.6	2722.4	2722.4	11387.3	11608.2	11608.2
1983	5.432	0.0	4.881	0.0	2691.7	2743.7	2743.7	11711.1	12005.0	12005.0
1984	5.652	0.0	5.332	0.0	2698.6	2765.0	2765.0	12016.5	12401.9	12401.9
1985	6.061	0.0	5.740	0.0	2718.3	2786.4	2786.4	12393.0	12798.8	12798.8
1986	6.508	0.0	6.169	0.0	2724.5	2807.7	2807.7	12690.3	13195.6	13195.6
1987	7.558	0.0	6.871	0.0	2728.5	2829.1	2829.1	12971.3	13562.5	13562.5
1988	7.734	0.0	7.337	0.0	2747.4	2850.4	2850.4	13334.1	13989.3	13985.3
1989	8.204	0.0	7.793	0.0	2749.6	2871.8	2871.8	13596.3	14386.2	14386.2
1990	8.630	0.0	8.235	0.0	2769.6	2893.1	2893.1	13966.5	14783.1	14783.1
2000	12.784	0.0	12.436	5.678	2921.2	3165.0	3165.0	18133.8	20098.5	20098.5
2010	18.749	12.662	18.253	12.413	3116.0	3350.8	3549.3	23148.9	25797.0	27326.5
2020	25.297	20.118	24.856	20.118	3384.7	3689.8	4057.8	29519.2	32962.5	37122.5

APPENDIX I. 1.2: SUMMARY OF LOSSES
UNIT:ALL RECEIVERS
SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL ACCC	NORMAL GC	DRAUGHT ACCC	DRAUGHT GC	POPULATION ACCC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ACCEC ACCC	TOTAL VALUE ACCEC GC	TOTAL VALUE ACCEC ENOUGH SUPPLY
1976	1.209	1.209	1.209	1.209	2583.1	2583.1	2611.6	9374.3	9374.3	9492.1
1977	0.940	0.940	0.940	0.940	2591.9	2591.9	2628.6	9673.1	9673.1	9822.7
1978	1.029	1.029	9.026	1.029	2599.7	2599.7	2645.6	9968.2	9968.2	10153.3
1979	1.144	1.144	57.784	1.144	2605.0	2605.0	2662.6	10252.3	10252.3	10483.9
1980	1.294	1.294	14.825	1.294	2603.0	2603.0	2679.7	10512.3	10512.3	10814.4
1981	1.170	1.170	3.733	1.170	2620.5	2620.5	2701.0	10886.4	10886.4	11211.3
1982	1.251	1.251	4.338	1.251	2636.4	2636.4	2722.4	11249.4	11249.4	11608.2
1983	1.358	1.358	4.991	1.358	2652.6	2652.6	2743.7	11615.0	11615.0	12005.0
1984	6.600	1.442	5.001	1.442	2640.4	2668.4	2765.0	11812.6	11976.4	12401.9
1985	6.165	1.519	5.693	1.519	2647.5	2685.8	2786.4	12118.5	12348.0	12798.8
1986	6.450	1.614	6.180	1.614	2653.7	2703.2	2807.7	12417.1	12718.2	13195.6
1987	6.893	1.713	6.625	1.713	2668.5	2719.1	2829.1	12762.1	13078.7	13592.5
1988	7.386	1.781	7.088	1.781	2670.5	2734.1	2850.4	13030.8	13437.2	13989.3
1989	7.850	1.885	7.550	1.885	2684.4	2748.8	2871.8	13371.6	13794.1	14386.2
1990	8.032	2.032	8.380	2.032	2683.6	2763.0	2893.1	13631.3	14159.6	14783.1
2000	12.469	2.898	12.227	2.898	2820.1	2963.9	3165.0	17720.9	18901.1	20098.5
2010	17.712	4.304	17.410	10.533	2992.8	3230.9	3549.3	22712.0	25067.8	27326.5
2020	24.138	17.738	23.778	17.445	3177.8	3421.9	4057.8	28539.8	31392.3	37122.5

APPENDIX I. 2.1: SUMMARY OF LOSSES
UNIT:CLUSTER NO. 1
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGC	NORMAL GC	DRAUGHT NCGC	DRAUGHT GC	POPULATION NCGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGC	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	201.8	201.8	201.8	233.1	233.1	233.1
1977	0.0	0.0	0.0	0.0	202.8	202.8	202.8	241.2	241.2	241.2
1978	0.0	0.0	0.752	0.0	203.7	203.7	203.7	249.2	249.2	249.2
1979	0.0	0.0	0.089	0.0	204.7	204.7	204.7	257.2	257.2	257.2
1980	0.0	0.0	0.646	0.0	205.6	205.6	205.6	265.3	265.3	265.3
1981	0.0	0.0	0.171	0.0	206.6	206.6	206.6	274.7	274.7	274.7
1982	0.303	0.0	0.193	0.0	204.7	207.6	207.6	279.5	284.0	284.0
1983	0.241	0.0	0.209	0.0	204.7	208.6	208.6	287.3	293.4	293.4
1984	0.247	0.0	0.229	0.0	204.6	209.6	209.6	294.7	302.8	302.8
1985	0.267	0.0	0.248	0.0	205.6	210.5	210.5	303.8	312.1	312.1
1986	0.282	0.0	0.263	0.0	205.4	211.5	211.5	311.0	321.5	321.5
1987	0.338	0.0	0.296	0.0	205.0	212.5	212.5	317.6	330.9	330.9
1988	0.340	0.0	0.316	0.0	205.5	213.5	213.5	326.6	340.3	340.3
1989	0.354	0.0	0.331	0.0	205.5	214.5	214.5	333.0	349.6	349.6
1990	0.380	0.0	0.354	0.0	206.5	215.5	215.5	342.0	359.0	359.0
2000	0.535	0.0	0.516	0.233	208.7	226.0	226.0	442.5	483.6	483.6
2010	0.750	0.501	0.723	0.488	209.9	228.7	239.1	557.2	612.8	643.5
2020	0.940	0.735	0.916	0.735	211.9	230.7	253.1	655.0	762.8	843.9

APPENDIX I. 2.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 1

SERVICE: NON SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.030	0.030	0.030	0.030	201.6	201.6	201.8	232.8	232.8	233.1
1977	0.029	0.029	0.029	0.029	202.6	202.6	202.8	240.9	240.9	241.2
1978	0.034	0.034	0.440	0.034	203.3	203.3	203.7	248.7	248.7	249.2
1979	0.038	0.038	3.148	0.038	204.3	204.3	204.7	256.7	256.7	257.2
1980	0.043	0.043	0.643	0.043	205.0	205.0	205.6	264.4	264.4	265.3
1981	0.055	0.055	0.167	0.055	205.7	205.7	206.6	273.3	273.3	274.7
1982	0.057	0.057	0.192	0.057	206.7	206.7	207.6	282.6	282.6	284.0
1983	0.080	0.080	0.238	0.080	207.0	207.0	208.6	290.8	290.8	293.4
1984	0.324	0.076	0.230	0.076	205.9	208.0	209.6	296.6	300.1	302.8
1985	0.301	0.092	0.273	0.092	205.6	208.6	210.5	303.8	308.7	312.1
1986	0.304	0.093	0.289	0.093	205.2	209.1	211.5	310.5	317.1	321.5
1987	0.326	0.099	0.310	0.099	206.2	210.1	212.5	319.6	326.4	330.9
1988	0.359	0.116	0.342	0.116	205.6	210.5	213.5	325.8	334.7	340.3
1989	0.375	0.116	0.357	0.116	206.0	210.9	214.5	333.7	342.8	349.6
1990	0.444	0.135	0.405	0.135	205.2	211.3	215.5	339.2	350.7	359.0
2000	0.566	0.170	0.552	0.170	208.4	219.2	226.0	441.2	466.8	483.6
2010	0.757	0.224	0.740	0.468	211.7	228.9	239.1	561.3	612.0	643.5
2020	0.950	0.704	0.929	0.687	215.4	232.4	253.1	705.9	767.1	843.9

APPENDIX I. 3.1: SUMMARY OF LOSSES
UNIT:CLUSTER NO. 2
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGO	NORMAL GO	CRALGHT NCGO	CRALGHT GO	POPULATION NCGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	335.8	335.8	335.8	682.8	682.8	682.8
1977	0.0	0.0	0.0	0.0	338.1	338.1	338.1	708.0	708.0	708.0
1978	0.0	0.0	2.461	0.0	340.5	340.5	340.5	733.2	733.2	733.2
1979	0.0	0.0	2.483	0.0	342.8	342.8	342.8	758.3	758.3	758.3
1980	0.0	0.0	3.159	0.0	345.2	345.2	345.2	783.5	783.5	783.5
1981	0.0	0.0	0.841	0.0	347.8	347.8	347.8	813.7	813.7	813.7
1982	1.174	0.0	0.969	0.0	344.9	350.5	350.5	831.3	843.8	843.8
1983	1.132	0.0	1.065	0.0	345.8	353.1	353.1	856.9	873.9	873.9
1984	1.201	0.0	1.164	0.0	346.4	355.7	355.7	881.8	904.1	904.1
1985	1.284	0.0	1.246	0.0	349.0	358.4	358.4	911.2	934.2	934.2
1986	1.387	0.0	1.347	0.0	349.4	361.0	361.0	935.3	964.4	964.4
1987	1.598	0.0	1.512	0.0	349.5	363.7	363.7	958.2	994.5	994.5
1988	1.655	0.0	1.607	0.0	352.0	366.3	366.3	987.2	1024.7	1024.7
1989	1.765	0.0	1.716	0.0	351.9	369.0	369.0	1009.2	1054.8	1054.8
1990	1.857	0.0	1.808	0.0	354.4	371.6	371.6	1038.0	1084.9	1084.9
2000	2.818	0.0	2.777	1.148	367.8	401.5	401.5	1379.4	1457.4	1457.4
2010	4.146	2.616	4.087	2.586	380.9	418.4	439.5	1784.9	1949.0	2041.3
2020	5.536	4.171	5.483	4.171	396.4	435.7	483.2	2280.5	2491.5	2747.4

APPENDIX I. 3.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 2

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.084	0.084	0.084	0.084	335.2	335.2	335.8	682.4	682.4	682.8
1977	0.084	0.084	0.084	0.084	337.5	337.5	338.1	707.5	707.5	708.0
1978	0.095	0.095	1.543	0.095	339.7	339.7	340.5	732.4	732.4	733.2
1979	0.106	0.106	2.790	0.106	341.9	341.9	342.8	757.5	757.5	758.3
1980	0.109	0.109	3.099	0.109	344.1	344.1	345.2	782.6	782.6	783.5
1981	0.127	0.127	0.694	0.127	346.6	346.6	347.8	812.3	812.3	813.7
1982	0.144	0.144	0.824	0.144	349.2	349.2	350.5	842.0	842.0	843.8
1983	0.162	0.162	0.964	0.162	351.6	351.6	353.1	871.6	871.6	873.9
1984	1.181	0.181	0.981	0.181	350.0	354.1	355.7	891.2	901.0	904.1
1985	1.204	0.198	1.144	0.198	350.9	356.5	358.4	916.6	930.3	934.2
1986	1.284	0.218	1.253	0.218	351.6	358.9	361.0	941.1	959.5	964.4
1987	1.377	0.226	1.343	0.226	353.8	361.3	363.7	969.2	988.5	994.5
1988	1.482	0.237	1.447	0.237	354.4	363.9	366.3	993.5	1018.5	1024.7
1989	1.588	0.262	1.551	0.262	356.7	366.3	369.0	1021.6	1047.3	1054.8
1990	1.820	0.283	1.738	0.283	356.7	368.6	371.6	1043.6	1076.0	1084.9
2000	2.612	0.380	2.583	0.380	374.9	396.7	401.5	1400.7	1477.1	1497.4
2010	3.709	0.502	3.672	1.864	395.9	432.5	439.5	1844.7	2003.4	2041.3
2020	5.056	3.284	5.012	3.245	416.6	454.8	483.2	2379.7	2583.1	2747.4

APPENDIX I. 4.1: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 3
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGO	NORMAL GO	DRAUGHT NCGO	DRAUGHT GO	POPULATION NCGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	797.1	797.1	797.1	4923.4	4923.4	4923.4
1977	0.0	0.0	0.0	0.0	797.0	797.0	797.0	5056.9	5056.9	5056.9
1978	0.0	0.0	6.554	0.0	796.9	796.9	796.9	5190.3	5190.3	5190.3
1979	0.0	0.0	26.413	0.0	796.7	796.7	796.7	5323.7	5323.7	5323.7
1980	0.0	0.0	5.329	0.0	796.6	796.6	796.6	5457.2	5457.2	5457.2
1981	0.0	0.0	1.412	0.0	796.5	796.5	796.5	5611.7	5611.7	5611.7
1982	2.548	0.0	1.553	0.0	782.4	796.4	796.4	5650.0	5766.3	5766.3
1983	1.978	0.0	1.693	0.0	778.1	796.3	796.3	5766.3	5920.8	5920.8
1984	1.985	0.0	1.829	0.0	773.0	796.2	796.2	5873.0	6075.4	6075.4
1985	2.109	0.0	1.951	0.0	772.5	796.1	796.1	6022.6	6230.0	6230.0
1986	2.258	0.0	2.081	0.0	767.5	796.0	796.0	6124.1	6384.5	6384.5
1987	2.656	0.0	2.300	0.0	761.5	795.9	795.9	6218.2	6539.1	6539.1
1988	2.645	0.0	2.447	0.0	761.1	795.8	795.8	6361.3	6693.6	6693.6
1989	2.785	0.0	2.574	0.0	754.6	795.7	795.7	6446.2	6848.2	6848.2
1990	2.927	0.0	2.721	0.0	754.5	795.6	795.6	6592.1	7002.8	7002.8
2000	3.912	0.0	3.738	1.783	721.5	794.7	794.7	8047.6	8967.9	8967.9
2010	5.218	3.640	4.968	3.527	684.5	759.2	801.0	9543.4	10705.6	11359.4
2020	6.255	5.060	6.030	5.060	652.2	722.6	807.5	11211.3	12559.4	14187.5

APPENDIX I. 4.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 3

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.063	0.063	0.063	0.063	794.8	794.8	797.1	4899.7	4899.7	4923.4
1977	0.045	0.045	0.045	0.045	793.8	793.8	797.0	5026.8	5026.8	5056.9
1978	0.049	0.049	3.610	0.049	792.4	792.4	796.9	5152.2	5152.2	5190.3
1979	0.056	0.056	27.711	0.056	790.7	790.7	796.7	5276.0	5276.0	5323.7
1980	0.073	0.073	5.179	0.073	786.9	786.9	796.6	5386.9	5386.9	5457.2
1981	0.025	0.025	0.985	0.025	786.7	786.7	796.5	5538.5	5538.5	5611.7
1982	0.026	0.026	1.182	0.026	786.5	786.5	796.4	5690.1	5690.1	5766.3
1983	0.027	0.027	1.385	0.027	786.3	786.3	796.3	5841.8	5841.8	5920.8
1984	2.171	0.029	1.332	0.029	775.4	785.7	796.2	5901.8	5990.6	6075.4
1985	1.808	0.027	1.555	0.027	771.7	785.5	796.1	6019.8	6142.2	6230.0
1986	1.832	0.028	1.691	0.028	767.4	785.3	796.0	6131.3	6293.7	6384.5
1987	1.950	0.029	1.809	0.029	767.2	785.1	795.9	6279.1	6445.3	6539.1
1988	2.103	0.030	1.944	0.030	762.0	784.5	795.8	6379.7	6596.8	6693.6
1989	2.227	0.031	2.069	0.031	761.8	784.7	795.7	6526.4	6748.4	6848.2
1990	2.654	0.032	2.305	0.032	756.4	784.5	795.6	6621.9	6899.9	7002.8
2000	3.341	0.042	3.215	0.042	735.4	783.0	794.7	8235.6	8830.7	8967.9
2010	4.404	0.049	4.246	2.132	715.1	788.0	801.0	10038.6	11171.2	11355.4
2020	5.535	3.678	5.347	3.543	688.7	757.6	807.5	11946.2	13258.4	14187.5

APPENDIX I. 5.1: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 4

SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	259.2	259.2	259.2	709.2	709.2	709.2
1977	0.0	0.0	0.0	0.0	261.5	261.5	261.5	731.0	731.0	731.0
1978	0.0	0.0	1.129	0.0	263.7	263.7	263.7	752.8	752.8	752.8
1979	0.0	0.0	4.191	0.0	265.9	265.9	265.9	774.6	774.6	774.6
1980	0.0	0.0	1.360	0.0	268.1	268.1	268.1	796.4	796.4	796.4
1981	0.0	0.0	0.363	0.0	270.8	270.8	270.8	828.3	828.3	828.3
1982	0.522	0.0	0.396	0.0	269.6	273.4	273.4	846.0	860.3	860.3
1983	0.490	0.0	0.448	0.0	270.9	276.1	276.1	872.4	892.2	892.2
1984	0.512	0.0	0.490	0.0	272.1	278.7	278.7	898.7	924.1	924.1
1985	0.561	0.0	0.536	0.0	274.6	281.4	281.4	929.1	956.1	956.1
1986	0.605	0.0	0.580	0.0	275.7	284.0	284.0	954.2	988.0	988.0
1987	0.658	0.0	0.651	0.0	276.7	286.7	286.7	978.8	1019.9	1019.9
1988	0.730	0.0	0.701	0.0	278.8	289.3	289.3	1007.2	1051.9	1051.9
1989	0.777	0.0	0.748	0.0	279.8	292.0	292.0	1031.4	1083.8	1083.8
1990	0.811	0.0	0.788	0.0	282.4	294.6	294.6	1061.9	1115.7	1115.7
2000	1.253	0.0	1.227	0.569	300.6	325.9	325.9	1435.8	1576.8	1576.8
2010	1.882	1.283	1.845	1.261	320.6	349.4	366.3	1912.9	2110.1	2226.4
2020	2.622	2.077	2.588	2.077	344.4	376.0	414.2	2539.2	2807.3	3128.9

APPENCIX I. 5.2: SLMMARY CF LOSSES

UNIT:CLLSTER NO. 4

SERVICE: ACh SERVED CALY

YEAR	CONCRETE LCSSES NORMAL NOGO	NORMAL GC	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.183	0.183	0.183	0.183	255.3	255.3	255.2	688.9	688.9	709.2
1977	0.153	0.153	0.153	0.153	256.1	256.1	261.5	704.5	704.5	731.0
1978	0.164	0.164	0.765	0.164	257.0	257.0	263.7	720.0	720.0	752.8
1979	0.170	0.170	4.218	0.170	257.8	257.8	265.9	734.1	734.1	774.6
1980	0.185	0.185	1.344	0.185	258.8	258.8	268.1	749.4	749.4	796.4
1981	0.180	0.180	0.403	0.180	260.7	260.7	270.8	776.2	776.2	828.3
1982	0.185	0.185	0.453	0.185	262.7	262.7	273.4	802.8	802.8	860.3
1983	0.197	0.197	0.514	0.197	265.0	265.0	276.1	831.3	831.3	892.2
1984	0.628	0.200	0.513	0.200	264.2	266.9	278.7	847.4	857.3	924.1
1985	0.614	0.212	0.582	0.212	265.5	269.3	281.4	871.6	885.8	956.1
1986	0.645	0.224	0.631	0.224	266.9	271.6	284.0	895.8	914.2	988.0
1987	0.697	0.234	0.678	0.234	268.9	273.9	286.7	922.7	942.6	1019.9
1988	0.743	0.239	0.722	0.239	270.0	276.3	289.3	946.0	971.0	1051.9
1989	0.781	0.248	0.763	0.248	272.3	278.6	292.0	973.8	999.5	1083.8
1990	0.894	0.257	0.846	0.257	273.0	280.9	294.6	995.0	1027.9	1115.7
2000	1.286	0.394	1.269	0.394	290.0	304.8	325.9	1336.0	1412.4	1576.8
2010	1.840	0.574	1.820	1.169	306.8	331.8	366.3	1748.4	1906.4	2226.4
2020	2.540	1.931	2.514	1.906	325.0	350.6	414.2	2265.7	2461.6	3128.9

APPENDIX I. 6.1: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 5
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGC	NORMAL GC	DRAUGHT NCGC	DRAUGHT GO	POPULATION NCGC	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGO	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	130.2	130.2	130.2	179.5	179.5	179.5
1977	0.0	0.0	0.0	0.0	133.0	133.0	133.0	188.8	188.8	188.8
1978	0.0	0.0	0.323	0.0	135.8	135.8	135.8	198.1	198.1	198.1
1979	0.0	0.0	1.289	0.0	138.6	138.6	138.6	207.3	207.3	207.3
1980	0.0	0.0	0.352	0.0	141.4	141.4	141.4	216.6	216.6	216.6
1981	0.0	0.0	0.095	0.0	145.1	145.1	145.1	230.5	230.5	230.5
1982	0.151	0.0	0.105	0.0	147.0	148.8	148.8	241.2	244.4	244.4
1983	0.129	0.0	0.116	0.0	150.2	152.4	152.4	254.0	258.3	258.3
1984	0.142	0.0	0.131	0.0	153.1	156.1	156.1	266.4	272.2	272.2
1985	0.154	0.0	0.144	0.0	156.6	159.8	159.8	279.8	286.1	286.1
1986	0.167	0.0	0.157	0.0	159.5	163.4	163.4	292.0	300.0	300.0
1987	0.198	0.0	0.179	0.0	162.2	167.1	167.1	303.6	313.9	313.9
1988	0.203	0.0	0.193	0.0	165.7	170.8	170.8	317.0	327.8	327.8
1989	0.222	0.0	0.210	0.0	168.2	174.4	174.4	328.2	341.7	341.7
1990	0.234	0.0	0.225	0.0	171.6	178.1	178.1	341.4	355.6	355.6
2000	0.429	0.0	0.419	0.194	211.1	226.6	226.6	542.3	585.4	585.4
2010	0.781	0.523	0.768	0.513	259.8	281.2	293.8	842.8	916.9	960.5
2020	1.286	1.010	1.275	1.010	321.1	349.9	385.0	1296.7	1420.3	1570.2

APPENDIX I. 6.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 5

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.154	0.154	0.154	0.154	124.7	124.7	130.2	170.0	170.0	179.5
1977	0.106	0.106	0.106	0.106	125.1	125.1	133.0	174.8	174.8	188.8
1978	0.107	0.107	0.250	0.107	125.4	125.4	135.8	179.4	179.4	198.1
1979	0.126	0.126	1.169	0.126	124.6	124.6	138.6	181.9	181.9	207.3
1980	0.168	0.168	0.420	0.168	120.0	120.0	141.4	177.0	177.0	216.6
1981	0.082	0.082	0.131	0.082	122.8	122.8	145.1	188.0	188.0	230.5
1982	0.088	0.088	0.147	0.088	125.6	125.6	148.8	198.9	198.9	244.4
1983	0.098	0.098	0.168	0.098	128.4	128.4	152.4	209.8	209.8	258.3
1984	0.203	0.103	0.171	0.103	130.1	131.0	156.1	218.8	220.5	272.2
1985	0.202	0.112	0.193	0.112	132.3	133.6	159.8	228.5	231.1	286.1
1986	0.220	0.120	0.212	0.120	134.4	136.2	163.4	238.2	241.7	300.0
1987	0.235	0.134	0.231	0.134	136.8	138.6	167.1	248.5	252.1	313.9
1988	0.261	0.147	0.254	0.147	138.6	140.8	170.8	257.7	262.3	327.8
1989	0.285	0.163	0.278	0.163	139.4	141.8	174.4	264.5	269.6	341.7
1990	0.358	0.215	0.346	0.215	139.4	142.4	178.1	271.4	277.7	355.6
2000	0.447	0.203	0.441	0.203	170.8	177.4	226.6	431.9	450.1	585.4
2010	0.769	0.329	0.761	0.535	209.9	224.4	293.8	674.9	725.0	960.5
2020	1.235	0.962	1.228	0.951	259.4	278.5	385.0	1044.0	1126.1	1570.2

APPENDIX I. 7.1: SUMMARY OF LOSSES
UNIT:CLUSTER NO. 6
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	231.6	231.6	231.6	474.5	474.5	474.5
1977	0.0	0.0	0.0	0.0	231.4	231.4	231.4	487.2	487.2	487.2
1978	0.0	0.0	1.365	0.0	231.1	231.1	231.1	499.8	499.8	499.8
1979	0.0	0.0	5.175	0.0	230.9	230.9	230.9	512.5	512.5	512.5
1980	0.0	0.0	1.353	0.0	230.6	230.6	230.6	525.2	525.2	525.2
1981	0.0	0.0	0.357	0.0	230.5	230.5	230.5	539.2	539.2	539.2
1982	0.572	0.0	0.402	0.0	225.9	230.3	230.3	537.7	553.1	553.1
1983	0.489	0.0	0.439	0.0	224.4	230.1	230.1	546.5	567.1	567.1
1984	0.501	0.0	0.473	0.0	222.7	229.9	229.9	554.4	581.1	581.1
1985	0.534	0.0	0.505	0.0	222.5	229.8	229.8	567.8	595.1	595.1
1986	0.570	0.0	0.540	0.0	220.7	229.6	229.6	574.7	605.0	605.0
1987	0.667	0.0	0.602	0.0	218.7	229.4	229.4	580.7	623.0	623.0
1988	0.669	0.0	0.634	0.0	218.5	229.2	229.2	593.8	637.0	637.0
1989	0.705	0.0	0.669	0.0	216.3	229.1	229.1	598.5	651.0	651.0
1990	0.745	0.0	0.707	0.0	216.1	228.9	228.9	611.5	664.9	664.9
2000	0.981	0.0	0.950	0.421	205.3	227.9	227.9	720.7	835.2	835.2
2010	1.285	0.863	1.241	0.842	194.2	216.8	229.6	826.6	965.2	1043.3
2020	1.517	1.200	1.478	1.200	184.8	206.2	232.1	944.6	1100.8	1288.9

APPENDIX I. 7.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 6

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	231.6	231.6	231.6	474.5	474.5	474.5
1977	0.0	0.0	0.0	0.0	231.4	231.4	231.4	487.2	487.2	487.2
1978	0.0	0.0	0.772	0.0	231.1	231.1	231.1	499.8	499.8	499.8
1979	0.0	0.0	5.421	0.0	230.9	230.9	230.9	512.5	512.5	512.5
1980	0.0	0.0	1.308	0.0	230.6	230.6	230.6	525.2	525.2	525.2
1981	0.0	0.0	0.245	0.0	230.5	230.5	230.5	539.2	539.2	539.2
1982	0.0	0.0	0.294	0.0	230.3	230.3	230.3	553.1	553.1	553.1
1983	0.0	0.0	0.345	0.0	230.1	230.1	230.1	567.1	567.1	567.1
1984	0.491	0.0	0.340	0.0	226.7	229.9	229.9	569.2	581.1	581.1
1985	0.443	0.0	0.398	0.0	225.4	229.8	229.8	578.6	595.1	595.1
1986	0.459	0.0	0.434	0.0	223.9	229.6	229.6	587.1	609.0	609.0
1987	0.490	0.0	0.464	0.0	223.7	229.4	229.4	600.6	623.0	623.0
1988	0.527	0.0	0.500	0.0	222.0	229.2	229.2	608.1	637.0	637.0
1989	0.562	0.0	0.533	0.0	221.9	229.1	229.1	621.5	651.0	651.0
1990	0.657	0.0	0.595	0.0	220.0	228.9	228.9	627.8	664.9	664.9
2000	0.829	0.0	0.807	0.0	213.0	227.9	227.9	759.6	835.2	835.2
2010	1.073	0.0	1.046	0.484	206.9	229.6	229.6	904.6	1043.3	1043.3
2020	1.330	0.847	1.297	0.823	199.8	221.3	232.1	1053.9	1210.1	1288.9

APPENDIX I. 8.1: SUMMARY OF LOSSES
UNIT:CLUSTER NO. 7
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGC	NORMAL GC	DRAUGHT NOGO	DRAUGHT GC	POPULATION NOGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	194.0	194.0	194.0	366.8	366.8	366.8
1977	0.0	0.0	0.0	0.0	197.4	197.4	197.4	386.0	386.0	386.0
1978	0.0	0.0	0.495	0.0	200.8	200.8	200.8	405.1	405.1	405.1
1979	0.0	0.0	1.772	0.0	204.2	204.2	204.2	424.3	424.3	424.3
1980	0.0	0.0	0.708	0.0	207.6	207.6	207.6	443.4	443.4	443.4
1981	0.0	0.0	0.194	0.0	211.8	211.8	211.8	470.5	470.5	470.5
1982	0.258	0.0	0.212	0.0	214.0	216.0	216.0	486.1	497.6	497.6
1983	0.258	0.0	0.243	0.0	217.4	220.2	220.2	508.4	524.7	524.7
1984	0.284	0.0	0.274	0.0	220.9	224.5	224.5	530.5	551.8	551.8
1985	0.308	0.0	0.299	0.0	224.8	228.7	228.7	555.0	578.8	578.8
1986	0.342	0.0	0.332	0.0	228.2	232.9	232.9	576.1	605.9	605.9
1987	0.391	0.0	0.373	0.0	231.4	237.1	237.1	595.4	633.0	633.0
1988	0.416	0.0	0.405	0.0	235.3	241.4	241.4	618.4	660.1	660.1
1989	0.451	0.0	0.439	0.0	238.2	245.6	245.6	635.7	687.2	687.2
1990	0.469	0.0	0.460	0.0	242.3	249.8	249.8	660.9	714.2	714.2
2000	0.827	0.0	0.815	0.387	285.1	302.4	302.4	931.4	1084.0	1084.0
2010	1.374	0.968	1.359	0.958	335.6	357.6	371.2	1270.5	1513.0	1665.7
2020	2.048	1.765	2.037	1.765	395.5	422.9	458.0	1694.1	2057.5	2534.0

APPENDIX I. 8.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 7

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NCGC	CONCRETE LOSSES NORMAL GC	CONCRETE LOSSES DRAUGHT NCGO	CONCRETE LOSSES DRAUGHT GO	POPULATION NCGC	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.282	0.282	0.282	0.282	187.6	187.6	194.0	336.2	336.2	366.8
1977	0.213	0.213	0.213	0.213	190.1	190.1	197.4	350.7	350.7	386.0
1978	0.243	0.243	0.460	0.243	191.9	191.9	200.8	364.2	364.2	405.1
1979	0.264	0.264	1.632	0.264	192.7	192.7	204.2	372.6	372.6	424.3
1980	0.295	0.295	0.744	0.295	193.5	193.5	207.6	383.3	383.3	443.4
1981	0.281	0.281	0.368	0.281	196.9	196.9	211.8	406.0	406.0	470.5
1982	0.313	0.313	0.419	0.313	199.7	199.7	216.0	424.3	424.3	497.6
1983	0.333	0.333	0.460	0.333	202.8	202.8	220.2	441.8	441.8	524.7
1984	0.503	0.342	0.468	0.342	204.7	205.9	224.5	454.9	461.8	551.8
1985	0.524	0.365	0.514	0.365	208.0	209.7	228.7	473.8	484.1	578.8
1986	0.555	0.384	0.549	0.384	210.9	213.1	232.9	490.1	503.5	605.9
1987	0.593	0.412	0.588	0.412	213.1	215.3	237.1	504.6	518.4	633.0
1988	0.615	0.415	0.608	0.415	216.7	219.5	241.4	524.7	543.6	660.1
1989	0.655	0.437	0.648	0.437	219.3	222.2	245.6	535.0	554.6	687.2
1990	0.704	0.453	0.690	0.453	221.6	225.3	249.8	550.5	576.4	714.2
2000	1.062	0.673	1.057	0.673	257.0	264.6	302.4	751.4	817.0	1084.0
2010	1.565	0.965	1.559	1.262	302.4	316.4	371.2	1045.8	1194.8	1665.7
2020	2.173	1.912	2.165	1.903	343.9	359.0	456.0	1269.0	1458.8	2534.0

APPENDIX I. 9.1: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 8
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGC	NORMAL GC	DRAUGHT NCGC	DRAUGHT GC	POPULATION NCGC	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGO	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	191.7	191.7	191.7	873.7	873.7	873.7
1977	0.0	0.0	0.0	0.0	193.2	193.2	193.2	921.5	921.5	921.5
1978	0.0	0.0	0.712	0.0	194.6	194.6	194.6	969.3	969.3	969.3
1979	0.0	0.0	2.417	0.0	196.1	196.1	196.1	1017.1	1017.1	1017.1
1980	0.0	0.0	0.963	0.0	197.5	197.5	197.5	1064.8	1064.8	1064.8
1981	0.0	0.0	0.259	0.0	199.1	199.1	199.1	1114.5	1114.5	1114.5
1982	0.341	0.0	0.288	0.0	198.6	200.6	200.6	1142.7	1164.1	1164.1
1983	0.326	0.0	0.310	0.0	199.7	202.2	202.2	1187.9	1213.7	1213.7
1984	0.359	0.0	0.344	0.0	200.5	203.7	203.7	1228.3	1263.3	1263.3
1985	0.387	0.0	0.374	0.0	201.7	205.3	205.3	1271.8	1313.0	1313.0
1986	0.401	0.0	0.394	0.0	202.8	206.9	206.9	1314.8	1362.6	1362.6
1987	0.439	0.0	0.423	0.0	204.0	208.4	208.4	1358.8	1412.2	1412.2
1988	0.478	0.0	0.460	0.0	204.8	210.0	210.0	1398.4	1461.8	1461.8
1989	0.499	0.0	0.486	0.0	206.0	211.5	211.5	1441.3	1511.5	1511.5
1990	0.521	0.0	0.509	0.0	207.0	213.1	213.1	1481.4	1561.1	1561.1
2000	0.829	0.0	0.814	0.388	217.4	230.0	230.0	1965.3	2162.6	2162.6
2010	1.206	0.845	1.186	0.836	228.6	242.4	250.5	2544.5	2803.6	2957.1
2020	1.614	1.340	1.592	1.340	239.0	254.7	273.0	3217.3	3569.0	3981.1

APPENDIX I. 9.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 8

SERVICE: NON SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.116	0.116	0.116	0.116	190.9	190.9	191.7	866.9	866.9	873.7
1977	0.090	0.090	0.090	0.090	192.3	192.3	193.2	914.4	914.4	921.5
1978	0.106	0.106	0.507	0.106	193.6	193.6	194.6	959.8	959.8	969.3
1979	0.118	0.118	2.437	0.118	194.7	194.7	196.1	1004.9	1004.9	1017.1
1980	0.142	0.142	0.990	0.142	195.6	195.6	197.5	1046.5	1046.5	1064.8
1981	0.122	0.122	0.288	0.122	197.5	197.5	199.1	1098.5	1098.5	1114.5
1982	0.123	0.123	0.322	0.123	199.0	199.0	200.6	1147.5	1147.5	1164.1
1983	0.124	0.124	0.354	0.124	200.6	200.6	202.2	1196.5	1196.5	1213.7
1984	0.416	0.126	0.361	0.126	200.6	202.1	203.7	1229.5	1245.5	1263.3
1985	0.403	0.128	0.392	0.128	201.6	203.7	205.3	1271.0	1294.5	1313.0
1986	0.433	0.130	0.422	0.130	202.8	205.2	206.9	1316.0	1343.5	1362.6
1987	0.464	0.137	0.454	0.137	203.5	206.4	208.4	1354.3	1388.7	1412.2
1988	0.491	0.139	0.480	0.139	204.8	208.0	210.0	1398.7	1437.6	1461.8
1989	0.522	0.141	0.510	0.141	205.9	209.5	211.5	1440.7	1486.5	1511.5
1990	0.557	0.143	0.542	0.143	207.0	211.1	213.1	1482.3	1535.3	1561.1
2000	0.842	0.199	0.832	0.199	218.7	227.1	230.0	1986.1	2116.6	2162.6
2010	1.206	0.271	1.194	0.738	231.5	245.9	250.5	2596.5	2868.6	2957.1
2020	1.616	1.220	1.601	1.208	243.8	258.6	273.0	3325.4	3655.7	3981.1

APPENDIX I.10.1: SUMMARY OF LOSSES
UNIT:CLUSTER NO. 9
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	71.7	71.7	71.7	190.6	190.6	190.6
1977	0.0	0.0	0.0	0.0	74.4	74.4	74.4	202.2	202.2	202.2
1978	0.0	0.0	0.088	0.0	77.2	77.2	77.2	213.7	213.7	213.7
1979	0.0	0.0	0.350	0.0	80.0	80.0	80.0	225.3	225.3	225.3
1980	0.0	0.0	0.142	0.0	82.7	82.7	82.7	236.8	236.8	236.8
1981	0.0	0.0	0.043	0.0	87.0	87.0	87.0	257.9	257.9	257.9
1982	0.060	0.0	0.049	0.0	90.7	91.2	91.2	277.7	279.0	279.0
1983	0.064	0.0	0.060	0.0	94.8	95.4	95.4	298.0	300.2	300.2
1984	0.075	0.0	0.071	0.0	98.8	99.7	99.7	318.4	321.3	321.3
1985	0.087	0.0	0.083	0.0	102.8	103.9	103.9	338.6	342.4	342.4
1986	0.101	0.0	0.097	0.0	106.9	108.1	108.1	359.1	363.5	363.5
1987	0.114	0.0	0.112	0.0	110.8	112.4	112.4	379.0	384.6	384.6
1988	0.127	0.0	0.125	0.0	114.9	116.6	116.6	399.8	405.8	405.8
1989	0.152	0.0	0.147	0.0	118.7	120.9	120.9	419.0	426.9	426.9
1990	0.156	0.0	0.155	0.0	122.8	125.1	125.1	439.5	448.0	448.0
2000	0.410	0.0	0.407	0.188	181.5	190.7	190.7	804.2	849.1	849.1
2010	0.965	0.630	0.962	0.622	269.4	285.7	285.9	1447.3	1539.8	1599.2
2020	1.976	1.527	1.973	1.527	396.1	427.3	463.1	2534.7	2751.1	2992.6

APPENDIX I.10.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 9

SERVICE: NEW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ACCEC NOGO	TOTAL VALUE ACCEC GO	TOTAL VALUE ACCEC ENOUGH SUPPLY
1976	0.160	0.160	0.160	0.160	64.3	64.3	71.7	172.4	172.4	190.6
1977	0.098	0.098	0.098	0.098	65.3	65.3	74.4	178.7	178.7	202.2
1978	0.100	0.100	0.110	0.100	66.5	66.5	77.2	185.5	185.5	213.7
1979	0.111	0.111	0.174	0.111	67.5	67.5	80.0	191.7	191.7	225.3
1980	0.117	0.117	0.149	0.117	67.7	67.7	82.7	195.4	195.4	236.8
1981	0.128	0.128	0.135	0.128	71.1	71.1	87.0	212.2	212.2	257.9
1982	0.129	0.129	0.140	0.129	73.9	73.9	91.2	226.6	226.6	279.0
1983	0.134	0.134	0.149	0.134	76.4	76.4	95.4	240.5	240.5	300.2
1984	0.177	0.158	0.174	0.158	79.6	79.7	99.7	256.6	256.7	321.3
1985	0.186	0.164	0.185	0.164	82.8	82.9	103.9	272.7	273.0	342.4
1986	0.205	0.177	0.203	0.177	86.2	86.3	108.1	289.0	289.4	363.5
1987	0.225	0.194	0.225	0.194	89.5	89.7	112.4	305.0	305.8	384.6
1988	0.224	0.184	0.223	0.184	91.6	91.8	116.6	317.3	318.1	405.8
1989	0.246	0.205	0.245	0.205	94.8	95.0	120.9	333.3	334.2	426.9
1990	0.274	0.224	0.273	0.224	97.5	98.2	125.1	349.1	350.2	448.0
2000	0.535	0.401	0.538	0.401	138.8	140.4	190.7	604.6	612.8	845.1
2010	1.108	0.795	1.107	0.947	192.2	197.7	295.9	1020.3	1055.4	1599.2
2020	2.030	1.812	2.030	1.805	257.0	266.0	463.1	1653.4	1724.4	2992.6

APPENDIX I.11.1: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 10
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGC	NORMAL GC	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	198.4	198.4	198.4	858.4	858.4	858.4
1977	0.0	0.0	0.0	0.0	199.8	199.8	199.8	900.1	900.1	900.1
1978	0.0	0.0	0.818	0.0	201.3	201.3	201.3	941.8	941.8	941.8
1979	0.0	0.0	2.995	0.0	202.8	202.8	202.8	983.5	983.5	983.5
1980	0.0	0.0	0.924	0.0	204.3	204.3	204.3	1025.2	1025.2	1025.2
1981	0.0	0.0	0.247	0.0	205.9	205.9	205.9	1070.4	1070.4	1070.4
1982	0.362	0.0	0.273	0.0	204.8	207.6	207.6	1095.1	1115.5	1115.5
1983	0.324	0.0	0.297	0.0	205.7	209.2	209.2	1133.5	1160.7	1160.7
1984	0.341	0.0	0.325	0.0	206.3	210.9	210.9	1170.3	1205.8	1205.8
1985	0.371	0.0	0.354	0.0	207.8	212.5	212.5	1213.4	1251.0	1251.0
1986	0.396	0.0	0.378	0.0	208.5	214.2	214.2	1248.9	1296.1	1296.1
1987	0.459	0.0	0.423	0.0	208.7	215.8	215.8	1281.1	1341.3	1341.3
1988	0.467	0.0	0.448	0.0	210.3	217.5	217.5	1324.5	1386.4	1386.4
1989	0.494	0.0	0.473	0.0	210.7	219.1	219.1	1356.7	1431.6	1431.6
1990	0.530	0.0	0.507	0.0	212.1	220.8	220.8	1397.9	1476.7	1476.7
2000	0.791	0.0	0.773	0.368	222.1	239.3	239.3	1864.6	2056.4	2056.4
2010	1.141	0.793	1.116	0.780	232.2	251.5	262.4	2418.8	2680.8	2829.9
2020	1.503	1.234	1.483	1.234	243.2	263.8	288.5	3105.9	3442.8	3847.8

APPENDIX I.11.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 10

SERVICE: NEW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NCGO	NORMAL GO	DRAUGHT NCGO	DRAUGHT GO	POPULATION NCGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.137	0.137	0.137	0.137	197.0	197.0	198.4	850.4	850.4	858.4
1977	0.122	0.122	0.122	0.122	197.8	197.8	199.8	887.9	887.9	900.1
1978	0.132	0.132	0.568	0.132	198.8	198.8	201.3	926.2	926.2	941.8
1979	0.155	0.155	3.083	0.155	199.9	199.9	202.8	964.5	964.5	983.5
1980	0.163	0.163	0.950	0.163	200.8	200.8	204.3	1001.7	1001.7	1025.2
1981	0.169	0.169	0.318	0.169	201.9	201.9	205.9	1042.3	1042.3	1070.4
1982	0.185	0.185	0.365	0.185	202.8	202.8	207.6	1081.4	1081.4	1115.5
1983	0.202	0.202	0.413	0.202	204.2	204.2	209.2	1123.9	1123.9	1160.7
1984	0.506	0.227	0.430	0.227	203.1	205.0	210.9	1146.6	1161.7	1205.8
1985	0.479	0.220	0.456	0.220	203.7	206.3	212.5	1182.2	1203.4	1251.0
1986	0.505	0.240	0.496	0.240	204.5	207.9	214.2	1218.1	1246.6	1296.1
1987	0.537	0.248	0.524	0.248	205.7	209.2	215.8	1258.5	1287.9	1341.3
1988	0.582	0.273	0.568	0.273	204.7	209.1	217.5	1279.4	1317.7	1386.4
1989	0.611	0.281	0.597	0.281	206.3	210.7	219.1	1321.0	1360.3	1431.6
1990	0.672	0.290	0.640	0.290	206.4	211.9	220.8	1350.6	1400.4	1476.7
2000	0.944	0.435	0.933	0.435	213.3	222.9	239.3	1773.8	1882.3	2056.4
2010	1.280	0.595	1.266	0.935	220.4	235.7	262.4	2276.8	2487.7	2829.9
2020	1.673	1.388	1.656	1.375	228.3	243.3	288.5	2896.5	3146.9	3847.8

APPENDIX I.12.1: SUMMARY OF LOSSES
UNIT:REVERE (CL. 1)
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	44.0	44.0	44.0	56.8	56.8	56.8
1977	0.0	0.0	0.0	0.0	44.2	44.2	44.2	58.8	58.8	58.8
1978	0.0	0.0	0.211	0.0	44.4	44.4	44.4	60.8	60.8	60.8
1979	0.0	0.0	0.839	0.0	44.7	44.7	44.7	62.8	62.8	62.8
1980	0.0	0.0	0.184	0.0	44.9	44.9	44.9	64.8	64.8	64.8
1981	0.0	0.0	0.048	0.0	45.1	45.1	45.1	67.2	67.2	67.2
1982	0.065	0.0	0.054	0.0	44.5	45.4	45.4	68.0	69.6	69.6
1983	0.068	0.0	0.059	0.0	44.4	45.6	45.6	69.9	72.0	72.0
1984	0.069	0.0	0.064	0.0	44.4	45.9	45.9	71.6	74.3	74.3
1985	0.073	0.0	0.068	0.0	44.6	46.1	46.1	73.9	76.7	76.7
1986	0.078	0.0	0.073	0.0	44.5	46.3	46.3	75.5	79.1	79.1
1987	0.093	0.0	0.082	0.0	44.3	46.6	46.6	77.0	81.4	81.4
1988	0.093	0.0	0.087	0.0	44.6	46.8	46.8	79.3	83.8	83.8
1989	0.098	0.0	0.092	0.0	44.3	47.1	47.1	80.6	86.2	86.2
1990	0.104	0.0	0.097	0.0	44.6	47.3	47.3	82.8	88.5	88.5
2000	0.143	0.0	0.138	0.063	44.7	49.8	49.8	106.8	120.4	120.4
2010	0.198	0.134	0.190	0.130	44.5	49.9	53.0	133.5	151.5	161.6
2020	0.245	0.193	0.238	0.193	44.4	49.8	56.3	165.0	187.1	213.7

APPENDIX I.12.2: SUMMARY OF LOSSES

UNIT:REVERE (CL. 1)
SERVICE: NOW SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	44.0	44.0	44.0	56.8	56.8	56.8
1977	0.0	0.0	0.0	0.0	44.2	44.2	44.2	58.8	58.8	58.8
1978	0.0	0.0	0.116	0.0	44.4	44.4	44.4	60.8	60.8	60.8
1979	0.0	0.0	0.883	0.0	44.7	44.7	44.7	62.8	62.8	62.8
1980	0.0	0.0	0.178	0.0	44.9	44.9	44.9	64.8	64.8	64.8
1981	0.0	0.0	0.033	0.0	45.1	45.1	45.1	67.2	67.2	67.2
1982	0.0	0.0	0.040	0.0	45.4	45.4	45.4	69.6	69.6	69.6
1983	0.0	0.0	0.047	0.0	45.6	45.6	45.6	72.0	72.0	72.0
1984	0.073	0.0	0.046	0.0	45.2	45.9	45.9	73.1	74.3	74.3
1985	0.062	0.0	0.054	0.0	45.2	46.1	46.1	75.0	76.7	76.7
1986	0.063	0.0	0.059	0.0	45.1	46.3	46.3	76.8	79.1	79.1
1987	0.068	0.0	0.063	0.0	45.4	46.6	46.6	79.1	81.4	81.4
1988	0.073	0.0	0.068	0.0	45.3	46.8	46.8	80.8	83.8	83.8
1989	0.078	0.0	0.073	0.0	45.5	47.1	47.1	83.0	86.2	86.2
1990	0.093	0.0	0.082	0.0	45.4	47.3	47.3	84.6	88.5	88.5
2000	0.121	0.0	0.117	0.0	46.5	49.8	49.8	111.4	120.4	120.4
2010	0.165	0.0	0.160	0.076	47.6	53.0	53.0	143.6	161.6	161.6
2020	0.214	0.137	0.209	0.132	48.2	53.6	56.3	180.4	202.6	213.7

APPENDIX I.13.1: SUMMARY OF LOSSES
UNIT:BELMONT (CL. 2)
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGC	NORMAL GC	DRAUGHT NCGC	DRAUGHT GC	POPULATION NCGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGC	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	29.1	29.1	29.1	34.7	34.7	34.7
1977	0.0	0.0	0.0	0.0	29.3	29.3	29.3	36.1	36.1	36.1
1978	0.0	0.0	0.222	0.0	29.6	29.6	29.6	37.4	37.4	37.4
1979	0.0	0.0	0.777	0.0	29.8	29.8	29.8	38.7	38.7	38.7
1980	0.0	0.0	0.273	0.0	30.0	30.0	30.0	40.0	40.0	40.0
1981	0.0	0.0	0.073	0.0	30.2	30.2	30.2	41.6	41.6	41.6
1982	0.103	0.0	0.083	0.0	29.9	30.5	30.5	42.4	43.2	43.2
1983	0.097	0.0	0.091	0.0	29.9	30.7	30.7	43.7	44.8	44.8
1984	0.102	0.0	0.099	0.0	30.0	31.0	31.0	44.9	46.4	46.4
1985	0.109	0.0	0.106	0.0	30.2	31.2	31.2	46.4	48.0	48.0
1986	0.117	0.0	0.114	0.0	30.2	31.4	31.4	47.6	49.6	49.6
1987	0.126	0.0	0.127	0.0	30.1	31.7	31.7	48.7	51.2	51.2
1988	0.139	0.0	0.135	0.0	30.4	31.9	31.9	50.2	52.8	52.8
1989	0.148	0.0	0.143	0.0	30.3	32.2	32.2	51.2	54.4	54.4
1990	0.156	0.0	0.151	0.0	30.5	32.4	32.4	52.7	56.0	56.0
2000	0.230	0.0	0.226	0.093	31.4	35.0	35.0	70.1	78.2	78.2
2010	0.329	0.209	0.324	0.206	32.0	35.9	38.1	90.1	101.3	107.5
2020	0.426	0.322	0.421	0.322	32.7	36.7	41.5	114.5	128.7	145.7

APPENDIX I.13.2: SUMMARY OF LOSSES

UNIT: BELMONT (CL. 2)
SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	29.1	29.1	29.1	34.7	34.7	34.7
1977	0.0	0.0	0.0	0.0	29.3	29.3	29.3	36.1	36.1	36.1
1978	0.0	0.0	0.131	0.0	29.6	29.6	29.6	37.4	37.4	37.4
1979	0.0	0.0	0.806	0.0	29.8	29.8	29.8	38.7	38.7	38.7
1980	0.0	0.0	0.264	0.0	30.0	30.0	30.0	40.0	40.0	40.0
1981	0.0	0.0	0.050	0.0	30.2	30.2	30.2	41.6	41.6	41.6
1982	0.0	0.0	0.060	0.0	30.5	30.5	30.5	43.2	43.2	43.2
1983	0.0	0.0	0.070	0.0	30.7	30.7	30.7	44.8	44.8	44.8
1984	0.090	0.0	0.070	0.0	30.5	31.0	31.0	45.7	46.4	46.4
1985	0.089	0.0	0.083	0.0	30.6	31.2	31.2	47.1	48.0	48.0
1986	0.094	0.0	0.091	0.0	30.8	31.4	31.4	48.3	49.6	49.6
1987	0.101	0.0	0.097	0.0	30.9	31.7	31.7	49.9	51.2	51.2
1988	0.109	0.0	0.105	0.0	30.9	31.9	31.9	51.1	52.8	52.8
1989	0.116	0.0	0.112	0.0	31.1	32.2	32.2	52.6	54.4	54.4
1990	0.134	0.0	0.126	0.0	31.1	32.4	32.4	53.7	56.0	56.0
2000	0.192	0.0	0.189	0.0	32.6	35.0	35.0	72.8	78.2	78.2
2010	0.270	0.0	0.266	0.114	34.2	38.1	38.1	96.4	107.5	107.5
2020	0.364	0.218	0.360	0.215	35.5	39.5	41.5	124.4	138.6	145.7

APPENDIX I.14.1: SUMMARY OF LOSSES

UNIT:BOSTON (CL. 3)
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	627.8	627.8	627.8	3739.4	3739.4	3739.4
1977	0.0	0.0	0.0	0.0	627.7	627.7	627.7	3840.7	3840.7	3840.7
1978	0.0	0.0	5.840	0.0	627.7	627.7	627.7	3942.1	3942.1	3942.1
1979	0.0	0.0	23.749	0.0	627.6	627.6	627.6	4043.4	4043.4	4043.4
1980	0.0	0.0	4.518	0.0	627.5	627.5	627.5	4144.7	4144.7	4144.7
1981	0.0	0.0	1.194	0.0	627.5	627.5	627.5	4262.2	4262.2	4262.2
1982	2.233	0.0	1.320	0.0	615.1	627.4	627.4	4283.3	4379.7	4379.7
1983	1.694	0.0	1.434	0.0	611.3	627.4	627.4	4368.1	4497.2	4497.2
1984	1.684	0.0	1.543	0.0	607.0	627.3	627.3	4447.2	4614.7	4614.7
1985	1.801	0.0	1.652	0.0	606.9	627.2	627.2	4560.6	4732.2	4732.2
1986	1.912	0.0	1.756	0.0	602.1	627.2	627.2	4632.8	4849.7	4849.7
1987	2.289	0.0	1.954	0.0	596.7	627.1	627.1	4658.7	4967.2	4967.2
1988	2.251	0.0	2.072	0.0	596.7	627.0	627.0	4810.0	5084.7	5084.7
1989	2.358	0.0	2.171	0.0	590.9	627.0	627.0	4868.1	5202.2	5202.2
1990	2.499	0.0	2.304	0.0	590.8	626.9	626.9	4978.3	5319.7	5319.7
2000	3.307	0.0	3.150	1.490	562.1	626.3	626.3	6064.7	6831.9	6831.9
2010	4.383	3.050	4.158	2.948	530.2	594.8	631.1	7165.8	8128.8	8670.5
2020	5.220	4.214	5.019	4.214	501.5	562.5	636.1	8381.0	9499.5	10846.4

APPENDIX I.14.2: SUMMARY OF LOSSES

UNIT:BOSTON (CL. 3)

SERVICE: NOW SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	627.8	627.8	627.8	3739.4	3739.4	3739.4
1977	0.0	0.0	0.0	0.0	627.7	627.7	627.7	3840.7	3840.7	3840.7
1978	0.0	0.0	3.165	0.0	627.7	627.7	627.7	3942.1	3942.1	3942.1
1979	0.0	0.0	25.064	0.0	627.6	627.6	627.6	4043.4	4043.4	4043.4
1980	0.0	0.0	4.367	0.0	627.5	627.5	627.5	4144.7	4144.7	4144.7
1981	0.0	0.0	0.819	0.0	627.5	627.5	627.5	4262.2	4262.2	4262.2
1982	0.0	0.0	0.985	0.0	627.4	627.4	627.4	4379.7	4379.7	4379.7
1983	0.0	0.0	1.157	0.0	627.4	627.4	627.4	4497.2	4497.2	4497.2
1984	1.891	0.0	1.117	0.0	618.3	627.3	627.3	4540.3	4614.7	4614.7
1985	1.543	0.0	1.310	0.0	614.9	627.2	627.2	4628.4	4732.2	4732.2
1986	1.546	0.0	1.420	0.0	611.1	627.2	627.2	4710.9	4849.7	4849.7
1987	1.660	0.0	1.527	0.0	611.0	627.1	627.1	4825.2	4967.2	4967.2
1988	1.776	0.0	1.635	0.0	606.7	627.0	627.0	4900.8	5084.7	5084.7
1989	1.897	0.0	1.748	0.0	606.7	627.0	627.0	5014.2	5202.2	5202.2
1990	2.269	0.0	1.949	0.0	601.8	626.9	626.9	5082.6	5319.7	5319.7
2000	2.815	0.0	2.701	0.0	583.9	626.3	626.3	6325.4	6831.9	6831.9
2010	3.695	0.0	3.553	1.755	566.5	631.1	631.1	7707.5	8670.5	8670.5
2020	4.630	3.056	4.461	2.933	544.2	605.3	636.1	9164.0	10282.5	10846.4

APPENDIX I.15.1: SUMMARY OF LOSSES

UNIT: PEABODY (CL. 4)
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	51.4	51.4	51.4	128.6	128.6	128.6
1977	0.0	0.0	0.0	0.0	52.0	52.0	52.0	132.9	132.9	132.9
1978	0.0	0.0	0.161	0.0	52.6	52.6	52.6	137.2	137.2	137.2
1979	0.0	0.0	0.561	0.0	53.2	53.2	53.2	141.5	141.5	141.5
1980	0.0	0.0	0.210	0.0	53.8	53.8	53.8	145.8	145.8	145.8
1981	0.0	0.0	0.058	0.0	54.5	54.5	54.5	152.1	152.1	152.1
1982	0.072	0.0	0.055	0.0	54.9	55.2	55.2	157.3	158.4	158.4
1983	0.076	0.0	0.069	0.0	55.4	55.9	55.9	162.9	164.7	164.7
1984	0.081	0.0	0.077	0.0	55.8	56.6	56.6	168.3	171.0	171.0
1985	0.088	0.0	0.084	0.0	56.5	57.3	57.3	174.5	177.3	177.3
1986	0.097	0.0	0.093	0.0	56.9	58.0	58.0	179.6	183.6	183.6
1987	0.106	0.0	0.101	0.0	57.6	58.7	58.7	185.8	189.9	189.9
1988	0.115	0.0	0.110	0.0	57.9	59.4	59.4	190.7	196.2	196.2
1989	0.124	0.0	0.119	0.0	58.6	60.1	60.1	196.8	202.5	202.5
1990	0.120	0.0	0.120	0.0	59.2	60.8	60.8	202.9	208.8	208.8
2000	0.211	0.0	0.206	0.098	64.7	68.6	68.6	281.1	300.0	300.0
2010	0.327	0.222	0.321	0.219	70.2	75.1	78.2	379.4	408.2	426.7
2020	0.476	0.367	0.468	0.367	76.2	82.1	89.0	506.1	548.6	595.0

APPENDIX I.15.2: SUMMARY OF LOSSES

UNIT: PEABODY (CL. 4)

SERVICE: NEW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	51.4	51.4	51.4	128.6	128.6	128.6
1977	0.0	0.0	0.0	0.0	52.0	52.0	52.0	132.9	132.9	132.9
1978	0.0	0.0	0.091	0.0	52.6	52.6	52.6	137.2	137.2	137.2
1979	0.0	0.0	0.577	0.0	53.2	53.2	53.2	141.5	141.5	141.5
1980	0.0	0.0	0.199	0.0	53.8	53.8	53.8	145.8	145.8	145.8
1981	0.0	0.0	0.042	0.0	54.5	54.5	54.5	152.1	152.1	152.1
1982	0.0	0.0	0.049	0.0	55.2	55.2	55.2	158.4	158.4	158.4
1983	0.0	0.0	0.056	0.0	55.9	55.9	55.9	164.7	164.7	164.7
1984	0.075	0.0	0.058	0.0	56.3	56.6	56.6	169.8	171.0	171.0
1985	0.069	0.0	0.066	0.0	56.8	57.3	57.3	175.4	177.3	177.3
1986	0.077	0.0	0.073	0.0	57.4	58.0	58.0	181.6	183.6	183.6
1987	0.086	0.0	0.082	0.0	57.9	58.7	58.7	186.9	189.9	189.9
1988	0.094	0.0	0.090	0.0	58.6	59.4	59.4	193.1	196.2	196.2
1989	0.091	0.0	0.091	0.0	59.2	60.1	60.1	199.3	202.5	202.5
1990	0.118	0.0	0.108	0.0	59.6	60.8	60.8	204.3	208.8	208.8
2000	0.185	0.0	0.181	0.0	65.9	68.6	68.6	286.9	300.0	300.0
2010	0.277	0.0	0.273	0.130	72.9	78.2	78.2	395.5	426.7	426.7
2020	0.411	0.273	0.405	0.268	79.9	85.5	89.0	533.1	573.3	595.0

APPENDIX I.16.1: SUMMARY OF LOSSES
UNIT:MEDFIELD (CL. 5)
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	11.2	11.2	11.2	10.0	10.0	10.0
1977	0.0	0.0	0.0	0.0	11.5	11.5	11.5	10.5	10.5	10.5
1978	0.0	0.0	0.003	0.0	11.7	11.7	11.7	11.1	11.1	11.1
1979	0.0	0.0	0.011	0.0	12.0	12.0	12.0	11.6	11.6	11.6
1980	0.0	0.0	0.006	0.0	12.3	12.3	12.3	12.2	12.2	12.2
1981	0.0	0.0	0.002	0.0	12.6	12.6	12.6	13.0	13.0	13.0
1982	0.003	0.0	0.002	0.0	13.0	13.0	13.0	13.8	13.8	13.8
1983	0.004	0.0	0.003	0.0	13.3	13.3	13.3	14.5	14.6	14.6
1984	0.005	0.0	0.004	0.0	13.6	13.6	13.6	15.3	15.4	15.4
1985	0.004	0.0	0.004	0.0	14.0	14.0	14.0	16.1	16.2	16.2
1986	0.006	0.0	0.006	0.0	14.3	14.3	14.3	16.9	17.0	17.0
1987	0.007	0.0	0.007	0.0	14.6	14.7	14.7	17.7	17.8	17.8
1988	0.007	0.0	0.007	0.0	15.0	15.0	15.0	18.5	18.6	18.6
1989	0.009	0.0	0.008	0.0	15.3	15.4	15.4	19.3	19.4	19.4
1990	0.010	0.0	0.010	0.0	15.6	15.7	15.7	20.0	20.2	20.2
2000	0.024	0.0	0.024	0.012	19.7	20.1	20.1	32.5	33.2	33.2
2010	0.053	0.033	0.053	0.033	24.4	25.4	25.9	50.5	52.6	53.8
2020	0.093	0.071	0.093	0.071	30.0	31.5	33.4	76.6	80.7	85.9

APPENDIX I.16.2: SUMMARY OF LOSSES

UNIT:MEDFIELD (CL. 5)

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.009	0.009	0.009	0.009	11.1	11.1	11.2	9.9	9.9	10.0
1977	0.008	0.008	0.008	0.008	11.4	11.4	11.5	10.4	10.4	10.5
1978	0.009	0.009	0.009	0.009	11.6	11.6	11.7	11.0	11.0	11.1
1979	0.010	0.010	0.010	0.010	11.8	11.8	12.0	11.4	11.4	11.6
1980	0.011	0.011	0.011	0.011	12.1	12.1	12.3	12.0	12.0	12.2
1981	0.014	0.014	0.014	0.014	12.4	12.4	12.6	12.7	12.7	13.0
1982	0.017	0.017	0.017	0.017	12.6	12.6	13.0	13.4	13.4	13.8
1983	0.020	0.020	0.020	0.020	12.9	12.9	13.3	14.0	14.0	14.6
1984	0.020	0.020	0.020	0.020	13.1	13.1	13.6	14.7	14.7	15.4
1985	0.024	0.024	0.024	0.024	13.3	13.3	14.0	15.3	15.3	16.2
1986	0.025	0.025	0.025	0.025	13.6	13.6	14.3	16.1	16.1	17.0
1987	0.027	0.027	0.027	0.027	13.8	13.8	14.7	16.7	16.7	17.8
1988	0.029	0.029	0.029	0.029	14.2	14.2	15.0	17.4	17.4	18.6
1989	0.034	0.034	0.034	0.034	14.3	14.3	15.4	17.9	17.9	19.4
1990	0.031	0.031	0.031	0.031	14.6	14.6	15.7	18.7	18.7	20.2
2000	0.061	0.061	0.061	0.061	17.2	17.2	20.1	28.0	28.0	33.2
2010	0.099	0.099	0.099	0.099	19.4	19.4	25.9	39.4	39.4	53.8
2020	0.146	0.146	0.146	0.146	22.2	22.2	33.4	55.9	55.9	85.9

APPENDIX I.17.1: SUMMARY OF LOSSES
UNIT:MEDFORD (CL. 6)
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	64.0	64.0	64.0	109.5	109.5	109.5
1977	0.0	0.0	0.0	0.0	64.1	64.1	64.1	112.8	112.8	112.8
1978	0.0	0.0	0.382	0.0	64.2	64.2	64.2	116.1	116.1	116.1
1979	0.0	0.0	1.468	0.0	64.3	64.3	64.3	119.3	119.3	119.3
1980	0.0	0.0	0.373	0.0	64.3	64.3	64.3	122.6	122.6	122.6
1981	0.0	0.0	0.098	0.0	64.4	64.4	64.4	126.4	126.4	126.4
1982	0.160	0.0	0.111	0.0	63.2	64.5	64.5	126.6	130.1	130.1
1983	0.136	0.0	0.122	0.0	62.9	64.6	64.6	129.2	133.9	133.9
1984	0.140	0.0	0.132	0.0	62.6	64.7	64.7	131.6	137.7	137.7
1985	0.149	0.0	0.141	0.0	62.7	64.8	64.8	135.2	141.4	141.4
1986	0.160	0.0	0.151	0.0	62.3	64.9	64.9	137.3	145.2	145.2
1987	0.189	0.0	0.170	0.0	61.8	64.9	64.9	139.2	149.0	149.0
1988	0.190	0.0	0.180	0.0	61.9	65.0	65.0	142.7	152.7	152.7
1989	0.201	0.0	0.190	0.0	61.4	65.1	65.1	144.3	156.5	156.5
1990	0.213	0.0	0.202	0.0	61.4	65.2	65.2	147.8	160.3	160.3
2000	0.284	0.0	0.275	0.121	59.3	66.1	66.1	180.0	207.7	207.7
2010	0.376	0.252	0.363	0.245	56.7	63.6	67.5	212.7	247.4	266.8
2020	0.447	0.352	0.436	0.352	54.4	61.1	69.0	249.6	289.6	337.9

APPENDIX I.17.2: SUMMARY OF LOSSES

UNIT:MEDFORD (CL. 6)
SERVICE: NEW SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	64.0	64.0	64.0	109.5	109.5	109.5
1977	0.0	0.0	0.0	0.0	64.1	64.1	64.1	112.8	112.8	112.8
1978	0.0	0.0	0.215	0.0	64.2	64.2	64.2	116.1	116.1	116.1
1979	0.0	0.0	1.539	0.0	64.3	64.3	64.3	119.3	119.3	119.3
1980	0.0	0.0	0.360	0.0	64.3	64.3	64.3	122.6	122.6	122.6
1981	0.0	0.0	0.067	0.0	64.4	64.4	64.4	126.4	126.4	126.4
1982	0.0	0.0	0.081	0.0	64.5	64.5	64.5	130.1	130.1	130.1
1983	0.0	0.0	0.096	0.0	64.6	64.6	64.6	133.9	133.9	133.9
1984	0.139	0.0	0.094	0.0	63.8	64.7	64.7	135.0	137.7	137.7
1985	0.125	0.0	0.111	0.0	63.5	64.8	64.8	137.7	141.4	141.4
1986	0.129	0.0	0.122	0.0	63.2	64.9	64.9	140.1	145.2	145.2
1987	0.138	0.0	0.131	0.0	63.3	64.9	64.9	143.8	149.0	149.0
1988	0.149	0.0	0.141	0.0	62.9	65.0	65.0	146.0	152.7	152.7
1989	0.160	0.0	0.151	0.0	63.0	65.1	65.1	149.6	156.5	156.5
1990	0.188	0.0	0.170	0.0	62.6	65.2	65.2	151.6	160.3	160.3
2000	0.240	0.0	0.233	0.0	61.6	66.1	66.1	189.4	207.7	207.7
2010	0.314	0.0	0.306	0.141	60.6	67.5	67.5	232.2	266.8	266.8
2020	0.391	0.248	0.382	0.241	59.1	65.7	65.0	277.6	317.7	337.9

APPENDIX I.18.1: SUMMARY OF LOSSES
UNIT:RANDOLPH (CL.7)
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	30.8	30.8	30.8	65.5	65.5	65.5
1977	0.0	0.0	0.0	0.0	31.5	31.5	31.5	69.1	69.1	69.1
1978	0.0	0.0	0.015	0.0	32.1	32.1	32.1	72.6	72.6	72.6
1979	0.0	0.0	0.049	0.0	32.7	32.7	32.7	76.1	76.1	76.1
1980	0.0	0.0	0.035	0.0	33.3	33.3	33.3	79.6	79.6	79.6
1981	0.0	0.0	0.009	0.0	34.1	34.1	34.1	84.7	84.7	84.7
1982	0.010	0.0	0.010	0.0	34.9	34.9	34.9	89.6	89.7	89.7
1983	0.014	0.0	0.013	0.0	35.6	35.6	35.6	94.3	94.7	94.7
1984	0.014	0.0	0.014	0.0	36.3	36.4	36.4	99.3	99.7	99.7
1985	0.015	0.0	0.015	0.0	37.1	37.2	37.2	104.3	104.8	104.8
1986	0.019	0.0	0.019	0.0	37.9	37.9	37.9	109.3	109.8	109.8
1987	0.019	0.0	0.019	0.0	38.6	38.7	38.7	114.3	114.8	114.8
1988	0.025	0.0	0.024	0.0	39.3	39.5	39.5	118.7	119.8	119.8
1989	0.025	0.0	0.025	0.0	40.1	40.2	40.2	123.6	124.9	124.9
1990	0.026	0.0	0.026	0.0	40.9	41.0	41.0	128.6	129.9	129.9
2000	0.058	0.0	0.057	0.017	50.1	50.4	50.4	196.1	199.4	199.4
2010	0.126	0.071	0.126	0.071	61.4	62.2	62.6	292.9	303.0	307.9
2020	0.229	0.181	0.229	0.181	74.5	75.7	77.6	424.0	440.2	468.9

APPENDIX I.18.2: SUMMARY OF LOSSES

UNIT:RANDOLPH (CL.7)

SERVICE: NON SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	CONCRETE LOSSES NORMAL GO	CONCRETE LOSSES DRAUGHT NOGO	CONCRETE LOSSES DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.058	0.058	0.058	0.058	30.0	30.0	30.8	61.0	61.0	65.5
1977	0.046	0.046	0.046	0.046	30.7	30.7	31.5	64.2	64.2	69.1
1978	0.052	0.052	0.052	0.052	31.3	31.3	32.1	67.5	67.5	72.6
1979	0.052	0.052	0.052	0.052	31.9	31.9	32.7	70.8	70.8	76.1
1980	0.059	0.059	0.059	0.059	32.3	32.3	33.3	72.5	72.5	79.6
1981	0.060	0.060	0.060	0.060	33.0	33.0	34.1	77.1	77.1	84.7
1982	0.068	0.068	0.068	0.068	33.7	33.7	34.9	81.7	81.7	89.7
1983	0.068	0.068	0.068	0.068	34.5	34.5	35.6	86.3	86.3	94.7
1984	0.076	0.076	0.076	0.076	34.9	34.9	36.4	88.8	88.8	99.7
1985	0.077	0.077	0.077	0.077	35.7	35.7	37.2	93.3	93.3	104.8
1986	0.080	0.080	0.080	0.080	36.4	36.4	37.9	97.8	97.8	109.8
1987	0.089	0.089	0.089	0.089	37.2	37.2	38.7	102.3	102.3	114.8
1988	0.089	0.089	0.089	0.089	37.9	37.9	39.5	106.8	106.8	119.8
1989	0.098	0.098	0.098	0.098	38.3	38.3	40.2	108.4	108.4	124.9
1990	0.105	0.105	0.105	0.105	39.0	39.0	41.0	112.8	112.8	129.9
2000	0.172	0.172	0.172	0.172	45.3	45.3	50.4	146.3	146.3	199.4
2010	0.254	0.254	0.254	0.254	53.5	53.5	62.6	196.9	196.9	307.9
2020	0.348	0.348	0.348	0.348	62.6	62.6	77.6	251.7	251.7	468.9

APPENDIX I.19.1: SUMMARY OF LOSSES

UNIT:NATICK (CL. 8)
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	32.3	32.3	32.3	177.2	177.2	177.2
1977	0.0	0.0	0.0	0.0	32.5	32.5	32.5	186.6	186.6	186.6
1978	0.0	0.0	0.045	0.0	32.7	32.7	32.7	196.1	196.1	196.1
1979	0.0	0.0	0.157	0.0	32.8	32.8	32.8	205.5	205.5	205.5
1980	0.0	0.0	0.090	0.0	33.0	33.0	33.0	214.9	214.9	214.9
1981	0.0	0.0	0.024	0.0	33.2	33.2	33.2	224.4	224.4	224.4
1982	0.028	0.0	0.025	0.0	33.4	33.5	33.5	233.3	233.9	233.9
1983	0.032	0.0	0.031	0.0	33.5	33.7	33.7	242.0	243.3	243.3
1984	0.031	0.0	0.031	0.0	33.7	33.9	33.9	251.5	252.8	252.8
1985	0.032	0.0	0.032	0.0	33.9	34.1	34.1	260.9	262.3	262.3
1986	0.039	0.0	0.037	0.0	34.2	34.3	34.3	270.3	271.7	271.7
1987	0.038	0.0	0.038	0.0	34.4	34.5	34.5	279.7	281.2	281.2
1988	0.046	0.0	0.044	0.0	34.6	34.7	34.7	289.1	290.6	290.6
1989	0.044	0.0	0.044	0.0	34.8	34.9	34.9	298.6	300.1	300.1
1990	0.045	0.0	0.045	0.0	35.0	35.1	35.1	308.0	309.6	309.6
2000	0.088	0.0	0.087	0.039	36.8	37.3	37.3	415.5	424.0	424.0
2010	0.143	0.095	0.141	0.095	38.5	39.6	40.0	552.0	563.9	571.6
2020	0.212	0.166	0.210	0.166	40.8	41.7	42.8	710.7	733.2	758.5

APPENDIX I.19.2: SUMMARY OF LOSSES

UNIT:NATICK (CL. 8)

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGC	NORMAL GC	DRAUGHT NOGO	DRAUGHT GC	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.116	0.116	0.116	0.116	31.4	31.4	32.3	170.4	170.4	177.2
1977	0.090	0.090	0.090	0.090	31.6	31.6	32.5	179.5	179.5	186.6
1978	0.106	0.106	0.106	0.106	31.6	31.6	32.7	186.6	186.6	196.1
1979	0.118	0.118	0.118	0.118	31.5	31.5	32.8	193.3	193.3	205.5
1980	0.142	0.142	0.142	0.142	31.1	31.1	33.0	196.6	196.6	214.9
1981	0.122	0.122	0.122	0.122	31.6	31.6	33.2	208.4	208.4	224.4
1982	0.123	0.123	0.123	0.123	31.8	31.8	33.5	217.2	217.2	233.9
1983	0.124	0.124	0.124	0.124	32.0	32.0	33.7	226.1	226.1	243.3
1984	0.126	0.126	0.126	0.126	32.2	32.2	33.9	234.9	234.9	252.8
1985	0.128	0.128	0.128	0.128	32.4	32.4	34.1	243.7	243.7	262.3
1986	0.130	0.130	0.130	0.130	32.6	32.6	34.3	252.6	252.6	271.7
1987	0.137	0.137	0.137	0.137	32.5	32.5	34.5	257.7	257.7	281.2
1988	0.139	0.139	0.139	0.139	32.7	32.7	34.7	266.4	266.4	290.6
1989	0.141	0.141	0.141	0.141	32.9	32.9	34.9	275.1	275.1	300.1
1990	0.143	0.143	0.143	0.143	33.1	33.1	35.1	283.8	283.8	309.6
2000	0.199	0.199	0.199	0.199	34.4	34.4	37.3	378.0	378.0	424.0
2010	0.271	0.271	0.271	0.271	35.3	35.3	40.0	483.1	483.1	571.6
2020	0.329	0.329	0.329	0.329	36.6	36.6	42.8	616.0	616.0	758.5

APPENDIX I.20.1: SUMMARY OF LOSSES

UNIT:NORTHBOROUGH (9)

SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	11.9	11.9	11.9	16.8	16.8	16.8
1977	0.0	0.0	0.0	0.0	12.4	12.4	12.4	17.8	17.8	17.8
1978	0.0	0.0	0.012	0.0	12.8	12.8	12.8	18.8	18.8	18.8
1979	0.0	0.0	0.046	0.0	13.3	13.3	13.3	19.8	19.8	19.8
1980	0.0	0.0	0.021	0.0	13.7	13.7	13.7	20.8	20.8	20.8
1981	0.0	0.0	0.006	0.0	14.4	14.4	14.4	22.7	22.7	22.7
1982	0.008	0.0	0.007	0.0	15.0	15.0	15.0	24.5	24.5	24.5
1983	0.009	0.0	0.008	0.0	15.6	15.7	15.7	26.3	26.4	26.4
1984	0.011	0.0	0.010	0.0	16.2	16.3	16.3	28.2	28.3	28.3
1985	0.013	0.0	0.012	0.0	16.8	17.0	17.0	29.9	30.1	30.1
1986	0.015	0.0	0.014	0.0	17.5	17.6	17.6	31.8	32.0	32.0
1987	0.017	0.0	0.017	0.0	18.1	18.3	18.3	33.5	33.8	33.8
1988	0.017	0.0	0.017	0.0	18.7	18.9	18.9	35.3	35.7	35.7
1989	0.021	0.0	0.020	0.0	19.4	19.6	19.6	37.2	37.5	37.5
1990	0.024	0.0	0.023	0.0	19.9	20.2	20.2	38.8	39.4	39.4
2000	0.061	0.0	0.060	0.027	28.6	29.8	29.8	71.2	74.2	74.2
2010	0.136	0.089	0.135	0.088	40.3	42.8	44.3	125.4	133.5	138.0
2020	0.261	0.199	0.261	0.199	56.3	60.7	65.8	216.2	233.0	253.0

APPENDIX I.20.2: SUMMARY OF LOSSES

UNIT:NORTHBOROUGH (9)

SERVICE: NCW SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	11.9	11.9	11.9	16.8	16.8	16.8
1977	0.0	0.0	0.0	0.0	12.4	12.4	12.4	17.8	17.8	17.8
1978	0.0	0.0	0.008	0.0	12.8	12.8	12.8	18.8	18.8	18.8
1979	0.0	0.0	0.048	0.0	13.3	13.3	13.3	19.8	19.8	19.8
1980	0.0	0.0	0.021	0.0	13.7	13.7	13.7	20.8	20.8	20.8
1981	0.0	0.0	0.004	0.0	14.4	14.4	14.4	22.7	22.7	22.7
1982	0.0	0.0	0.006	0.0	15.0	15.0	15.0	24.5	24.5	24.5
1983	0.0	0.0	0.007	0.0	15.7	15.7	15.7	26.4	26.4	26.4
1984	0.009	0.0	0.008	0.0	16.2	16.3	16.3	28.2	28.3	28.3
1985	0.010	0.0	0.009	0.0	16.9	17.0	17.0	30.0	30.1	30.1
1986	0.012	0.0	0.011	0.0	17.5	17.6	17.6	31.9	32.0	32.0
1987	0.012	0.0	0.012	0.0	18.2	18.3	18.3	33.7	33.8	33.8
1988	0.015	0.0	0.014	0.0	18.8	18.9	18.9	35.4	35.7	35.7
1989	0.017	0.0	0.017	0.0	19.4	19.6	19.6	37.3	37.5	37.5
1990	0.020	0.0	0.019	0.0	20.0	20.2	20.2	39.0	39.4	39.4
2000	0.050	0.0	0.049	0.0	29.0	29.8	29.8	72.3	74.2	74.2
2010	0.114	0.0	0.112	0.055	41.7	44.3	44.3	129.9	138.0	138.0
2020	0.223	0.146	0.223	0.143	59.1	63.2	65.8	226.9	242.8	253.0

APPENDIX I.21.1: SUMMARY OF LOSSES

UNIT:BRAINTREE (C.10)
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	38.7	38.7	38.7	176.7	176.7	176.7
1977	0.0	0.0	0.0	0.0	39.2	39.2	39.2	186.3	186.3	186.3
1978	0.0	0.0	0.049	0.0	39.8	39.8	39.8	195.8	195.8	195.8
1979	0.0	0.0	0.165	0.0	40.3	40.3	40.3	205.4	205.4	205.4
1980	0.0	0.0	0.091	0.0	40.9	40.9	40.9	215.0	215.0	215.0
1981	0.0	0.0	0.024	0.0	41.5	41.5	41.5	226.5	226.5	226.5
1982	0.030	0.0	0.025	0.0	42.0	42.1	42.1	237.0	238.1	238.1
1983	0.032	0.0	0.030	0.0	42.6	42.8	42.8	248.5	249.6	249.6
1984	0.037	0.0	0.036	0.0	43.3	43.4	43.4	260.0	261.2	261.2
1985	0.043	0.0	0.041	0.0	43.8	44.0	44.0	270.5	272.7	272.7
1986	0.049	0.0	0.047	0.0	44.4	44.7	44.7	281.9	284.3	284.3
1987	0.055	0.0	0.053	0.0	44.9	45.3	45.3	292.1	295.8	295.8
1988	0.054	0.0	0.054	0.0	45.5	45.9	45.9	303.5	307.3	307.3
1989	0.063	0.0	0.061	0.0	46.1	46.6	46.6	314.9	318.9	318.9
1990	0.070	0.0	0.067	0.0	46.5	47.2	47.2	324.4	330.4	330.4
2000	0.133	0.0	0.130	0.058	52.7	54.5	54.5	471.6	491.0	491.0
2010	0.224	0.1445	0.221	0.144	59.2	61.9	63.5	660.3	696.4	718.5
2020	0.335	0.2644	0.335	0.264	66.4	69.7	74.0	910.9	965.4	1035.5

APPENDIX I.21.2: SUMMARY OF LOSSES

UNIT: BRAINTREE (C.10)
SERVICE: NEW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.115	0.115	0.115	0.115	37.4	37.4	38.7	169.3	169.3	176.7
1977	0.099	0.099	0.099	0.099	37.3	37.3	39.2	174.6	174.6	186.3
1978	0.105	0.105	0.105	0.105	37.5	37.5	39.8	181.3	181.3	195.8
1979	0.125	0.125	0.125	0.125	37.6	37.6	40.3	187.5	187.5	205.4
1980	0.129	0.129	0.129	0.129	37.7	37.7	40.9	193.3	193.3	215.0
1981	0.131	0.131	0.131	0.131	37.8	37.8	41.5	200.4	200.4	226.5
1982	0.138	0.138	0.138	0.138	37.8	37.8	42.1	206.9	206.9	238.1
1983	0.146	0.146	0.146	0.146	38.4	38.4	42.8	217.0	217.0	249.6
1984	0.163	0.163	0.163	0.163	38.4	38.4	43.4	222.7	222.7	261.2
1985	0.153	0.153	0.153	0.153	38.9	38.9	44.0	232.6	232.6	272.7
1986	0.169	0.169	0.169	0.169	39.5	39.5	44.7	242.5	242.5	284.3
1987	0.164	0.164	0.164	0.164	40.1	40.1	45.3	252.5	252.5	295.8
1988	0.188	0.188	0.188	0.188	39.3	39.3	45.9	251.2	251.2	307.3
1989	0.191	0.191	0.191	0.191	39.8	39.8	46.6	260.7	260.7	318.9
1990	0.186	0.186	0.186	0.186	40.4	40.4	47.2	270.2	270.2	330.4
2000	0.270	0.270	0.270	0.270	43.0	43.0	54.5	363.8	363.8	491.0
2010	0.358	0.358	0.358	0.358	46.3	46.3	63.5	489.5	489.5	718.5
2020	0.471	0.471	0.471	0.471	50.8	50.8	74.0	669.2	669.2	1035.5

II. CONCRETE LOSSES OF POTENTIAL RECEIVERS

APPENDIX II.1.1.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: NOGO
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL CITY	EMER CITY	RVNUE COMMERCE	SPRINKLNG BUS.INVST	COM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.402	0.913	2.157	0.204	0.530	0.0	2.085	6.291
1983	0.461	1.042	2.508	0.237	0.600	0.0	0.584	5.432
1984	0.501	1.120	2.771	0.258	0.643	0.0	0.358	5.652
1985	0.543	1.204	2.960	0.280	0.688	0.0	0.386	6.061
1986	0.581	1.280	3.229	0.302	0.727	0.0	0.389	6.508
1987	0.636	1.406	3.623	0.336	0.793	0.0	0.764	7.558
1988	0.665	1.500	3.843	0.363	0.840	0.0	0.502	7.734
1989	0.723	1.579	4.148	0.386	0.880	0.0	0.488	8.204
1990	0.766	1.663	4.348	0.411	0.920	0.0	0.522	8.630
2000	1.173	2.359	6.759	0.701	1.318	0.0	0.474	12.784
2010	1.686	3.216	10.106	1.140	1.853	0.0	0.749	18.749
2020	2.249	4.105	13.898	1.713	2.465	0.0	0.866	25.296

APPENDIX II.1.1.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL
ALTERNATIVE: NOCO
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:DRAUGHT

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVALE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.704	1.682	3.486	0.350	0.988	0.0	7.487	14.698
1979	1.795	4.169	8.672	0.890	2.462	0.0	38.065	56.074
1980	1.495	3.410	7.055	0.738	2.008	0.0	0.230	14.935
1981	0.407	0.915	1.892	0.201	0.534	0.0	0.034	3.983
1982	0.424	0.964	2.266	0.216	0.559	0.0	0.012	4.441
1983	0.461	1.042	2.508	0.237	0.600	0.0	0.033	4.881
1984	0.501	1.120	2.771	0.258	0.643	0.0	0.038	5.332
1985	0.543	1.204	2.960	0.280	0.688	0.0	0.065	5.740
1986	0.581	1.280	3.229	0.302	0.727	0.0	0.050	6.169
1987	0.636	1.406	3.623	0.336	0.793	0.0	0.077	6.871
1988	0.685	1.500	3.843	0.363	0.840	0.0	0.105	7.337
1989	0.723	1.579	4.148	0.386	0.880	0.0	0.077	7.793
1990	0.766	1.663	4.348	0.411	0.920	0.0	0.127	8.235
2000	1.173	2.359	6.759	0.701	1.318	0.0	0.126	12.436
2010	1.686	3.216	10.106	1.140	1.853	0.0	0.253	18.253
2020	2.249	4.105	13.898	1.713	2.465	0.0	0.425	24.855

APPENDIX II.1.2.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: NOGC
SERVICE: NEW SERVED ONLY
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.085	0.128	0.313	0.023	0.177	0.0	0.484	1.209
1977	0.093	0.141	0.361	0.026	0.192	0.0	0.127	0.940
1978	0.100	0.153	0.410	0.028	0.205	0.0	0.133	1.029
1979	0.103	0.162	0.461	0.031	0.215	0.0	0.173	1.144
1980	0.101	0.164	0.513	0.032	0.214	0.0	0.269	1.294
1981	0.107	0.174	0.556	0.035	0.222	0.0	0.075	1.170
1982	0.113	0.185	0.609	0.038	0.232	0.0	0.074	1.251
1983	0.120	0.198	0.665	0.041	0.243	0.0	0.090	1.358
1984	0.460	0.993	2.553	0.227	0.669	0.0	1.698	6.600
1985	0.519	1.124	2.931	0.260	0.738	0.0	0.593	6.165
1986	0.559	1.207	3.212	0.284	0.782	0.0	0.407	6.450
1987	0.600	1.290	3.434	0.309	0.825	0.0	0.438	6.895
1988	0.638	1.369	3.727	0.331	0.864	0.0	0.457	7.386
1989	0.677	1.453	3.953	0.355	0.905	0.0	0.506	7.850
1990	0.739	1.589	4.396	0.394	0.971	0.0	0.943	9.032
2000	1.117	2.246	6.656	0.672	1.347	0.0	0.430	12.469
2010	1.582	3.007	9.643	1.072	1.804	0.0	0.604	17.712
2020	2.020	3.836	13.520	1.624	2.334	0.0	0.803	24.138

APPENDIX II.1.2.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: ACOC
SERVICE: NEW SERVED ONLY
RUNOFF CONDITION:DRAUGHT

YEAR	INDUSTRIAL CITY	EMER CITY	REVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.085	0.128	0.313	0.023	0.177	0.0	0.484	1.209
1977	0.093	0.141	0.361	0.026	0.192	0.0	0.127	0.940
1978	0.532	1.241	2.687	0.257	0.807	0.0	3.502	9.026
1979	1.693	4.086	8.670	0.873	2.377	0.0	40.085	57.784
1980	1.392	3.286	7.044	0.715	1.929	0.0	0.459	14.825
1981	0.357	0.770	1.803	0.167	0.547	0.0	0.090	3.733
1982	0.418	0.901	2.104	0.199	0.617	0.0	0.099	4.337
1983	0.480	1.038	2.421	0.233	0.690	0.0	0.130	4.991
1984	0.460	0.993	2.553	0.227	0.669	0.0	0.099	5.001
1985	0.519	1.124	2.931	0.260	0.738	0.0	0.121	5.693
1986	0.559	1.207	3.212	0.284	0.782	0.0	0.137	6.180
1987	0.600	1.290	3.434	0.307	0.825	0.0	0.168	6.625
1988	0.638	1.369	3.727	0.331	0.864	0.0	0.160	7.088
1989	0.677	1.453	3.953	0.355	0.905	0.0	0.207	7.550
1990	0.739	1.589	4.396	0.394	0.971	0.0	0.291	8.380
2000	1.117	2.246	6.656	0.672	1.347	0.0	0.188	12.227
2010	1.582	3.007	9.643	1.072	1.804	0.0	0.302	17.410
2020	2.020	3.836	13.520	1.624	2.334	0.0	0.444	23.778

APPENDIX II.2.1.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL
ALTERNATIVE: GO
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	1.395	2.323	6.039	0.800	1.291	0.0	0.814	12.662
2020	2.233	3.485	10.123	1.411	2.022	0.0	0.839	20.118

APPENDIX II.2.1.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: GO
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:DRAUGHT

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.685	1.219	2.511	0.353	0.662	0.0	0.248	5.678
2010	1.355	2.323	6.039	0.800	1.291	0.0	0.565	12.413
2020	2.233	3.485	10.123	1.411	2.022	0.0	0.839	20.118

APPENDIX II.2.2.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: GO
SERVICE: NOW SERVED ONLY
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVAUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.085	0.128	0.313	0.023	0.177	0.0	0.484	1.209
1977	0.093	0.141	0.361	0.026	0.192	0.0	0.127	0.940
1978	0.100	0.153	0.410	0.028	0.205	0.0	0.133	1.029
1979	0.103	0.162	0.461	0.031	0.215	0.0	0.173	1.144
1980	0.101	0.164	0.513	0.032	0.214	0.0	0.269	1.294
1981	0.107	0.174	0.556	0.035	0.222	0.0	0.075	1.170
1982	0.113	0.185	0.609	0.038	0.232	0.0	0.074	1.251
1983	0.120	0.198	0.665	0.041	0.243	0.0	0.090	1.358
1984	0.125	0.208	0.717	0.044	0.252	0.0	0.095	1.442
1985	0.132	0.220	0.767	0.048	0.263	0.0	0.090	1.519
1986	0.139	0.231	0.818	0.051	0.273	0.0	0.102	1.614
1987	0.145	0.242	0.873	0.054	0.284	0.0	0.114	1.713
1988	0.150	0.251	0.920	0.057	0.290	0.0	0.113	1.781
1989	0.154	0.260	0.977	0.060	0.298	0.0	0.135	1.885
1990	0.162	0.269	1.034	0.064	0.305	0.0	0.198	2.032
2000	0.243	0.396	1.602	0.116	0.434	0.0	0.106	2.898
2010	0.346	0.559	2.435	0.196	0.603	0.0	0.161	4.304
2020	1.676	2.857	9.257	1.186	1.826	0.0	0.935	17.738

APPENDIX II.2.2.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: GO
SERVICE: NOW SERVED ONLY
RUNOFF CONDITION:DROUGHT

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	CON.INVST	TOTAL
1976	0.085	0.128	0.313	0.023	0.177	0.0	0.484	1.209
1977	0.093	0.141	0.361	0.026	0.192	0.0	0.127	0.940
1978	0.100	0.153	0.410	0.028	0.205	0.0	0.133	1.029
1979	0.103	0.162	0.461	0.031	0.215	0.0	0.173	1.144
1980	0.101	0.164	0.513	0.032	0.214	0.0	0.269	1.294
1981	0.107	0.174	0.556	0.035	0.222	0.0	0.075	1.170
1982	0.113	0.185	0.609	0.038	0.232	0.0	0.074	1.251
1983	0.120	0.198	0.665	0.041	0.243	0.0	0.090	1.358
1984	0.125	0.208	0.717	0.044	0.252	0.0	0.095	1.442
1985	0.132	0.220	0.767	0.048	0.263	0.0	0.090	1.519
1986	0.139	0.231	0.818	0.051	0.273	0.0	0.102	1.614
1987	0.145	0.242	0.873	0.054	0.284	0.0	0.114	1.713
1988	0.150	0.251	0.920	0.057	0.290	0.0	0.113	1.781
1989	0.154	0.260	0.977	0.060	0.298	0.0	0.135	1.885
1990	0.162	0.269	1.034	0.064	0.305	0.0	0.198	2.032
2000	0.243	0.396	1.602	0.116	0.434	0.0	0.106	2.898
2010	1.105	1.873	5.214	0.654	1.231	0.0	0.454	10.533
2020	1.676	2.857	9.257	1.186	1.826	0.0	0.642	17.445

APPENDIX II.3.1.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL
ALTERNATIVE: NET GC OVER NOGC
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.402	0.913	2.157	0.204	0.530	0.0	2.085	6.291
1983	0.461	1.042	2.508	0.237	0.600	0.0	0.584	5.432
1984	0.501	1.120	2.771	0.258	0.643	0.0	0.358	5.652
1985	0.543	1.204	2.960	0.280	0.688	0.0	0.386	6.061
1986	0.581	1.280	3.229	0.302	0.727	0.0	0.389	6.508
1987	0.636	1.406	3.623	0.336	0.793	0.0	0.764	7.558
1988	0.685	1.500	3.843	0.363	0.840	0.0	0.502	7.734
1989	0.723	1.579	4.148	0.386	0.880	0.0	0.488	8.204
1990	0.766	1.663	4.348	0.411	0.920	0.0	0.522	8.630
2000	1.173	2.359	6.759	0.701	1.318	0.0	0.474	12.784
2010	0.290	0.853	4.067	0.340	0.562	0.0	-0.065	6.087
2020	0.015	0.616	3.776	0.302	0.443	0.0	0.027	5.179

APPENDIX II.3.1.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL
ALTERNATIVE: NET GO OVER NOGO
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:DRAUGHT

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.704	1.682	3.486	0.350	0.988	0.0	7.487	14.658
1979	1.795	4.189	8.672	0.890	2.462	0.0	38.065	56.074
1980	1.495	3.410	7.055	0.738	2.008	0.0	0.230	14.935
1981	0.407	0.915	1.892	0.201	0.534	0.0	0.034	3.983
1982	0.424	0.964	2.266	0.216	0.559	0.0	0.012	4.441
1983	0.461	1.042	2.508	0.237	0.600	0.0	0.033	4.881
1984	0.501	1.120	2.771	0.258	0.643	0.0	0.038	5.332
1985	0.543	1.204	2.960	0.280	0.688	0.0	0.065	5.740
1986	0.581	1.280	3.229	0.302	0.727	0.0	0.050	6.169
1987	0.636	1.406	3.623	0.336	0.793	0.0	0.077	6.871
1988	0.685	1.500	3.943	0.363	0.840	0.0	0.105	7.337
1989	0.723	1.579	4.148	0.386	0.880	0.0	0.077	7.793
1990	0.766	1.663	4.348	0.411	0.920	0.0	0.127	8.235
2000	0.488	1.140	4.248	0.348	0.656	0.0	-0.122	6.758
2010	0.290	0.853	4.067	0.340	0.562	0.0	-0.312	5.840
2020	0.015	0.616	3.776	0.302	0.443	0.0	-0.414	4.738

APPENDIX II.3.2.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: NET GC OVER NOGC
SERVICE: NOW SERVED ONLY
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.335	0.785	1.836	0.182	0.417	0.0	1.603	5.158
1985	0.387	0.904	2.164	0.213	0.475	0.0	0.503	4.646
1986	0.420	0.976	2.394	0.233	0.509	0.0	0.305	4.836
1987	0.454	1.047	2.561	0.253	0.542	0.0	0.325	5.182
1988	0.487	1.118	2.807	0.273	0.574	0.0	0.345	5.605
1989	0.523	1.193	2.976	0.295	0.607	0.0	0.371	5.965
1990	0.577	1.319	3.362	0.330	0.666	0.0	0.746	7.000
2000	0.874	1.850	5.054	0.556	0.913	0.0	0.324	9.571
2010	1.236	2.448	7.204	0.877	1.200	0.0	0.443	13.408
2020	0.344	0.979	4.262	0.438	0.508	0.0	-0.131	6.400

APPENDIX II.3.2.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: NET GO OVER NOGO
SERVICE: NOW SERVED ONLY
RUNOFF CONDITION:DRAUGHT

YEAR	INDUSTRIAL CITY:	FAER CITY:	RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	DOM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.433	1.088	2.277	0.229	0.602	0.0	3.369	7.997
1979	1.590	3.924	8.209	0.842	2.163	0.0	35.913	56.640
1980	1.291	3.122	6.530	0.683	1.714	0.0	0.190	13.531
1981	0.250	0.596	1.246	0.132	0.325	0.0	0.014	2.563
1982	0.304	0.716	1.495	0.161	0.385	0.0	0.025	3.087
1983	0.360	0.840	1.756	0.192	0.446	0.0	0.039	3.633
1984	0.335	0.785	1.836	0.182	0.417	0.0	0.004	3.559
1985	0.387	0.904	2.164	0.213	0.475	0.0	0.021	4.174
1986	0.420	0.976	2.394	0.233	0.509	0.0	0.035	4.566
1987	0.454	1.047	2.561	0.253	0.542	0.0	0.055	4.912
1988	0.487	1.118	2.807	0.273	0.574	0.0	0.047	5.308
1989	0.523	1.193	2.976	0.295	0.607	0.0	0.072	5.664
1990	0.577	1.319	3.362	0.330	0.666	0.0	0.093	6.348
2000	0.874	1.850	5.054	0.556	0.913	0.0	0.082	9.329
2010	0.476	1.134	4.429	0.418	0.572	0.0	-0.152	6.877
2020	0.344	0.979	4.262	0.438	0.508	0.0	-0.198	6.333

III. SAMPLE COMMUNITY PROFILES — A. SUPPLIERS

PROFILE: Athol

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	32.34 sq. mi.
	CHARACTER: Industrial/Residential	res. 4.0%; indus. 0.4%; vacant 87.8% public lands 3.0%
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1965	11,989
	AGE COMPOSITION	50.4% 20-64
	RACIAL COMPOSITION	
	White; Negro; Other	99.3%; .6%; .1%
	Foreign Stock: (48.9% Canad.; 9.8% Ital.; 8.8% Russ.; 8.2% U.K.; 8.0% Lith.)	40.1%
	GROWTH TRENDS	
	1950-1960:	.7% incr.; net out-migration 1,046
	1955-1965:	1.6% decr.; net out-migration 1,234
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1967	$14,526,939
	TOTAL REVENUES, 1967	$ 1,597,963
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	99
	Wholesale (7 firms) 1968 Payroll:	$339,000
	Retail (92 firms) 1963 Sales Per Capita:	$ 1,311
5. HOUSING	NEW UNITS BUILT, 1960-1970	162
	EXISTING UNITS, 1970	3,866
	VACANCY RATE, 1960	4.8%
6. EDUCATION	PRESENT ATTENDANCE, K-12 (1969)	2514
	PRESENT CLASSROOM SPACE, K-12 (1971)	51 classrooms
	TEACHERS CURRENTLY EMPLOYED (1969-1970)	48
	PUPIL-TEACHER RATIO: Elementary; Secondary	U
	TEACHER SALARY RANGE (1968-1969)	$5,750 - $9,516
	COST PER PUPIL	$448
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	Ample

U=unobtainable data at this level of detail
N/A=not applicable

PROFILE: Athol

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	186.34 acres
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	0
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS	U.S.#20; Mass. #32,#2,#24
	AIR	Orange Municipal Airport
	RAIL	Boston & Maine RR (freight)
	BUS	Local bus franchises
	TRUCK	Local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	Athol Water Dept.: ground & Surface sources
	PRESENT GARBAGE COLLECTION SYSTEM	Combined garbage & refuse weekly
	PRESENT RESIDENTIAL INSURANCE RATE	N/A
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	N/A
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	1 (Planning Board)
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	2
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	0
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Athol

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968 (18 firms):	$ 127,000
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll, 1966 (230 firms)	$22,953,000
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 5,394
	PRESENT TAX REVENUE, 1967	$1,597,963
	PRESENT REGIONAL INCOME: 1959 Median Family Income, Worcester County	$ 5,977
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960	
	Private	3,902
	Government	379
	Self-Employed	310
	Unpaid Family Workers	15
	PRESENT UNEMPLOYMENT (1972 regional)	7.4% (Athol Labor Area)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	230
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: Erving

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	14.04 sq. mi.
	CHARACTER:	Industrial/Residential
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	1,260; 90/sq. mi.
	AGE COMPOSITION	49.2% 20-64
	RACIAL COMPOSITION	U
	White:	
	Foreign Stock:	
	GROWTH TRENDS	
	1950-1960:	3.8% decrease; net out-migration 147
	1955-1965:	2.3% decrease; net out-migration 144
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION,1970	$9,972,611
	TOTAL REVENUES 1970	$ 398,904
	ASSESSMENTS IN PROJECT AREA	U
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	10
	TOTAL ANNUAL PAYROLL, 1968	$75,068
5. HOUSING	NEW UNITS BUILT,1960-1970	19
	EXISTING UNITS,	U
	VACANCY RATE,	U
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private	353; 4
	PRESENT CLASSROOM SPACE, K-6	10
	TEACHERS CURRENTLY EMPLOYED	11
	PUPIL-TEACHER RATIO	15.2
	TEACHER SALARY RANGE	$6500-$11,000
	COST PER PUPIL	$741
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	Ample

U=unobtainable data at this level of detail
N/A=not applicable

PROFILE: Erving

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	U
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	0
9. TRANSPORTATION	MAJOR ARTERIES	Rtes. 2 & 63
	AIR	0
	RAIL	Boston & Maine RR (freight)
	BUS, TRUCK	Local franchises: Englander, Western Mass.
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM :	None in Erving Center; Ervingside: Millers Falls Water District
	PRESENT GARBAGE COLLECTION SYSTEM	Combined garbage & refuse weekly
	PRESENT RESIDENTIAL INSURANCE RATE	N/A
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	N/A
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	1 (Planning Board)
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	0
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	0
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Erving

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll,	U
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll	U
17. REAL INCOME	MEDIAN FAMILY INCOME,	U
	PRESENT TAX REVENUE, 1970	$398,904
	TOTAL ANNUAL PAYROLL	$8,542,022
	REGIONAL INCOME: 1959 Median Family Income, Franklin County	$5,455
18. EMPLOYMENT	PRESENT EMPLOYMENT,	U
	PRESENT UNEMPLOYMENT (1972 regional)	7.4%
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	23
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: **Greenfield**

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	21.47 sq. mi.
	CHARACTER: Industrial/Residential	22.6% developed; 2.2% cultivated; 51.1% wooded; 22.3% other open
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	18,084; 842/sq. mi.
	AGE COMPOSITION, 1960	64.3% 20-64 yrs.
	RACIAL COMPOSITION	
	White:	99.3%
	Foreign Stock: (26.2% Canadian; 21.5% Polish; 10.1% U.K.; 9.8% Irish; 7.2% German)	28.1%
	GROWTH TRENDS	
	1950-1960:	2.0% increase; net out-migration 1,323
	1955-1965:	1.1% increase; net out-migration 959
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1969	$83,858,835
	TOTAL REVENUES, 1964	$ 4,025,223
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS	122; $1,099,049
	Wholesale, 1968; Payroll	217; $2,743
	Retail, 1967; Sales Per Capita	
5. HOUSING	NEW UNITS BUILT, 1960-1970	574
	EXISTING UNITS, 1960	5,179
	VACANCY RATE, 1960	4.4%
6. EDUCATION	PRESENT ATTENDANCE, K-12 (1969)	3,589
	PRESENT CLASSROOM SPACE, K-12	162 classrooms
	TEACHERS CURRENTLY EMPLOYED (1969-1970)	177
	PUPIL-TEACHER RATIO: Elementary; Secondary (1969-1970)	19.9; 15.7
	TEACHER SALARY RANGE	$6,700 - $11,800
	COST PER PUPIL (1968-1969)	$659
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	Ample

Unascertainable data at this level of detail
N/A-not applicable

PROFILE: Greenfield

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	U
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	0
9. TRANSPORTATION	MAJOR ARTERIES, HIGHWAY	I-91, U.S. #5, Mass. #2, #10
	AIR	None
	RAIL	Boston & Maine RR (freight)
	BUS, TRUCK	Local franchises offering local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	Greenfield Water Department
	PRESENT GARBAGE COLLECTION SYSTEM	Combined garbage & refuse weekly
	PRESENT RESIDENTIAL INSURANCE RATE	N/A
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	N/A
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	1(Planning Board)
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	0
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	0
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PRIMARY: Greenfield

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968	$1,503,629
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll	$35,918,547
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$5,692
	PRESENT TAX REVENUE, 1969	$4,025,223
	REGIONAL INCOME: 1959 Median Family Income, Franklin County	$5,455
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960	
	Private	5,345
	Government	797
	Self-Employed	596
	Unpaid Family Workers	39
	PRESENT UNEMPLOYMENT (1972 regional)	9.8% (Greenfield Labor Area)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	469
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: Orange

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	35.03 sq. mi.
	CHARACTER:	Industrial/Residential
	TOTAL ACREAGE TAKEN FOR PROJECT:	36 (2 road & pipeline; 34 dam)
	USE IN PROJECT AREA:	Forested open space
2. POPULATION	TOTAL,1970; DENSITY	6,104; 174/sq. mi.
	AGE COMPOSITION:	48.0% 20-64 yrs.
	RACIAL COMPOSITION: White; Negro; Other	100%
	Foreign Stock	25.6%
	GROWTH TRENDS 1950-1960:	4.4% incr.; net out-migration 380
	1955-1965:	0.7% incr.; net out-migration 371
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION,1970	$12,938,820
	TOTAL REVENUES, 1970	$ 1,166,293
	ASSESSMENTS IN PROJECT AREA	U
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	53
	Wholesale (5 firms) 1968 Payroll:	$ 98,092
	Retail (48 firms) 1968 Payroll	$917,690
5. HOUSING	NEW UNITS BUILT,1960-1970	61
	EXISTING UNITS, 1970	1,417
	VACANCY RATE,1960	6.2%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1969-1970)	1,520; 75
	PRESENT CLASSROOM SPACE, K-12 (1971)	80 classrooms (incl. regional H.S.)
	TEACHERS CURRENTLY EMPLOYED (1969-1970)	32
	PUPIL-TEACHER RATIO: Elementary; Secondary	25.2; U
	TEACHER SALARY RANGE, (1971-1972)	$6,750 - $11,300
	COST PER PUPIL (1969-1970)	$686
	PRESENT BUSING	None in Project Area
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	Ample

U = Unattainable data at this level of detail
N/A = not applicable

PROFILE: Orange

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	10 acres
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	0
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS	U.S.#202; Mass.#122,2,2A,78
	AIR	Municipal Airport
	RAIL	Boston & Maine RR (freight)
	BUS	Local franchises
	TRUCK	Local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	Orange Water Dept. - ground & surface sources
	PRESENT GARBAGE COLLECTION SYSTEM	Combined garbage & refuse weekly
	PRESENT RESIDENTIAL INSURANCE RATE	N/A
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	N/A
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	2 (Millers River Watershed Assoc.; Planning Board)
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	3
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	1
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

********** SHAFT COST **********

SHAFT NO	SEG NO	********** COST IN DOLLARS PER FOOT OF SHAFT ********** EXC SETUP	EXC	MUCK LOAD	MUCK HOIST	MUCK DISP	SUP-PORTS	LIN-ING	LIN FRM	GROUT	SEG COST ($/FT)	SEGMENT LENGTH (FEET)	SEGMENT COST ($1000)
1	2 L	0	1656	131	409	156	0	70	98	0	2520		252
	E	0	636	42	42	81	0	11	32	278	1122		112
	M	0	102	45	0	2	113	136	25	43	466		46
	T	0	2394	218	451	239	113	217	155	321	4108	100	410
1	3 L	0	644	51	163	68	0	64	98	0	1088		598
	E	0	247	16	16	36	0	10	32	0	357		196
	M	0	93	38	0	2	55	80	25	0	293		161
	T	0	984	105	179	106	55	154	155	0	1738	550	955

REGIONAL FACTOR	COST 1.20	COST INDEX	- - LABOR	1.30	SHAFT LABOR COST..... 850
			EQUIPMENT	1.10	SHAFT EQUIPMENT COST..... 308
			MATERIALS	1.22	SHAFT MATERIALS COST..... 207
					SHAFT COST..... 1365

********** SHAFT COST **********

SHAFT NO	SEG NO		COST IN DOLLARS PER FOOT OF SHAFT								SEG COST ($/FT)	SEGMENT LENGTH (FEET)	SEGMENT COST ($1000)
		EXC SETUP	EXC	MUCK LOAD	MUCK HOIST	MUCK DISP	SUP-PORTS	LIN-ING	LIN FORM	GROUT			
2	4 L	0	1376	131	409	152	0	64	80	0	2212		221
	E	0	513	42	39	78	0	10	26	232	940		94
	M	0	79	27	0	2	67	90	19	34	318		31
	T	0	1968	200	448	232	67	164	125	266	3470	100	346
2	5 L	0	507	48	151	61	0	60	80	0	907		36
	E	0	189	15	14	32	0	9	26	0	285		11
	M	0	70	23	0	2	42	57	19	0	213		8
	T	0	766	86	165	95	42	126	125	0	1405	40	55

REGIONAL COST FACTOR 1.20

COST INDEX -- LABOR 1.30, EQUIPMENT 1.10, MATERIALS 1.22

SHAFT LABOR COST..... 257
SHAFT EQUIPMENT COST..... 105
SHAFT MATERIALS COST..... 39
SHAFT COST..... 401

********** SHAFT COST **********

SHAFT NO	SEG NO	COST IN DOLLARS PER FOOT OF SHAFT									SEG COST ($/FT)	SEGMENT LENGTH (FEET)	SEGMENT COST ($1000)
		EXC SETUP	EXC	MUCK LOAD	MUCK HDIST	MUCK DISP	SUP-PORTS	LIN-ING	LIN FORM	GROUT			
3	6 L	0	1376	131	409	152	0	64	80	0	2212		221
	E	0	513	42	39	78	0	10	26	232	940		94
	M	0	79	27	0	2	67	90	19	34	318		31
	T	0	1968	200	448	232	67	164	125	266	3470	100	346
3	7 L	0	529	50	159	64	0	60	80	0	942		235
	E	0	197	16	15	33	0	9	26	0	296		74
	M	0	71	23	0	2	42	57	19	0	214		53
	T	0	797	89	174	99	42	126	125	0	1452	250	362
3	8 L	0	529	50	162	64	0	61	80	0	946		160
	E	0	197	16	15	33	0	9	26	0	296		50
	M	0	71	23	0	2	42	57	19	0	214		36
	T	0	797	89	177	99	42	127	125	0	1456	170	246

REGIONAL FACTOR COST 1.20

COST INDEX -- LABOR 1.30
EQUIPMENT 1.10
MATERIALS 1.22

SHAFT LABOR COST.....616
SHAFT EQUIPMENT COST.....218
SHAFT MATERIALS COST.....120
SHAFT COST.....954

********** SHAFT COST **********

SHAFT NO	SEG NO		COST IN DOLLARS PER FOOT OF SHAFT								SEG COST ($/FT)	SEGMENT LENGTH (FEET)	SEGMENT COST ($1000)
			EXC SETUP	EXC	MUCK LOAD	MUCK HDIST	MUCK DISP	SUP-PORTS	LIN-ING	LIN FRM	GROUT			
4	9	L	0	1376	131	409	152	0	64	80	0	2212		221
		E	0	513	42	39	78	0	10	26	232	940		94
		M	0	77	27	0	2	67	90	19	34	316		31
		T	0	1966	200	448	232	67	164	125	266	3468	100	346
4	10	L	0	554	53	167	67	0	61	80	0	982		265
		E	0	206	17	16	34	0	9	26	0	308		83
		M	0	67	24	0	2	47	63	19	0	222		59
		T	0	827	94	183	103	47	133	125	0	1512	270	407

REGIONAL COST FACTOR 1.20

COST INDEX -- LABOR 1.30
EQUIPMENT 1.10
MATERIALS 1.22

SHAFT LABOR COST..... 486
SHAFT EQUIPMENT COST..... 177
SHAFT MATERIALS COST..... 90
SHAFT COST..... 753

********** SHAFT COST **********

SHAFT NO	SEG NO	COST IN DOLLARS PER FOOT OF SHAFT									SEG COST ($/FT)	SEGMENT LENGTH (FEET)	SEGMENT COST ($1000)
		EXC SETUP	EXC	MUCK LOAD	MUCK HOIST	MUCK DISP	SUP-PORTS	LIN-ING	LIN FORM	GROUT			
5	11 L	0	1376	131	409	150	0	64	80	0	2210		331
	E	0	513	42	39	77	0	10	26	232	939		140
	M	0	79	27	0	1	67	90	19	34	317		47
	T	0	1968	200	448	228	67	164	125	266	3466	150	518
5	12 L	0	529	50	159	62	0	60	80	0	940		84
	E	0	197	16	15	32	0	9	26	0	295		26
	M	0	71	23	0	1	42	57	19	0	213		19
	T	0	797	89	174	95	42	126	125	0	1448	90	129

REGIONAL FACTOR 1.20

COST INDEX -- LABOR 1.30
EQUIPMENT 1.10
MATERIALS 1.22

SHAFT LABOR COST..... 415
SHAFT EQUIPMENT COST..... 166
SHAFT MATERIALS COST..... 66
SHAFT COST..... 647

********** TUNNEL REACH COST SUMMARY **********

REACH	EXIT SHAFT	REGIONAL COST FACTOR	**** COST INDEXES ****** LABOR	EQUIP	MATL	********** COSTS ($1000) ********** LABOR	EQUIPMENT	MATERIAL	TOTAL
1	2	1.20	1.30	1.10	1.22	1056	204	204	1464
2	2	1.20	1.30	1.10	1.22	4548	908	1022	6478
3	3	1.20	1.30	1.10	1.22	4555	998	1139	6692
4	4	1.20	1.30	1.10	1.22	4992	1301	1138	7431

SHAFT COST SUMMARY

SHAFT	REGIONAL COST FACTOR	COST INDEXES LABOR	COST INDEXES EQUIP	COST INDEXES MATL	COSTS ($1000) LABOR	COSTS ($1000) EQUIPMENT	COSTS ($1000) MATERIAL	COSTS ($1000) TOTAL
1	1.20	1.30	1.10	1.22	850	308	207	1365
2	1.20	1.30	1.10	1.22	257	105	39	401
3	1.20	1.30	1.10	1.22	616	218	120	954
4	1.20	1.30	1.10	1.22	486	177	90	753
5	1.20	1.30	1.10	1.22	415	166	66	647

****
* NORTHFIELD MT. TO RATTLESNAKE HILL *
* ALINEMENT NO. 16 MDC *
* MOLE EXCAVATION *
****

PROFIT MARGIN 5.00
OVERHEAD MARGIN 25.00

TOTAL TUNNEL	LABOR COST.....($1000)	15151
TOTAL TUNNEL	EQUIPMENT COST.....	3411
TOTAL TUNNEL	MATERIAL COST.....	3503
TOTAL TUNNEL	COST.....	22065
TOTAL SHAFT	LABOR COST.....	2624
TOTAL SHAFT	EQUIPMENT COST.....	974
TOTAL SHAFT	MATERIAL COST.....	522
TOTAL SHAFT	COST.....	4120
TOTAL PROJECT	LABOR COST.....	17775
TOTAL PROJECT	EQUIPMENT COST	4385
TOTAL PROJECT	MATERIAL COST	4025
TOTAL PROJECT	COST	26185

CORPS OF ENGINEERS U. S. ARMY

LEGEND

(16) TUNNEL ALINEMENT NUMBER

[3] SHAFT NUMBER AND APPROXIMATE LOCATION

GRAPHIC SCALE

1" = 2000' 2000' 0 2000' 4000'

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

NORTHFIELD MOUNTAIN
WATER SUPPLY PROJECT

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE C-1

APPENDIX D

WATER QUALITY STUDIES OF CONNECTICUT AND MILLERS RIVERS AND QUABBIN AND WACHUSETT RESERVOIRS

This appendix was prepared by New England Research, Inc. jointly for the Commonwealth of Massachusetts Metropolitan District Commission and the New England Division, U. S. Army, Corps of Engineers. The report covers possible effects on Quabbin Reservoir from both the Northfield Mountain and Millers River Basin Water Supply Projects as well as the possible effects on the Connecticut and Millers Rivers watersheds. As such, some parts of this appendix may not apply directly to this report. However, one must be cognizant of the close relationship of the two projects and their effects.

A large amount of field and laboratory data on water quality as well as hydrodynamic studies, fisheries information and pollution abatement plans were collected, considered and evaluated. Evaluations made in this appendix were then used to analyze the various projects for acceptability as water supply sources and for their effect on the environment.

Water Quality Studies
Connecticut and Millers River Systems
and
Quabbin and Wachusett Reservoirs
Massachusetts

Northeastern United States
Water Supply Study

Sponsored by the

Commonwealth of Massachusetts
Metropolitan District Commission

and

New England Division, U. S. Army Corps of Engineers
Contract No. DACW 33-71-C-0056

Prepared By

New England Research, Inc.

With The Technical Assistance of

Alden Research Laboratories
of Worcester Polytechnic Institute
Clark University
Mason Research Institute
University of Massachusetts
Worcester Polytechnic Institute

June 1972

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SYNOPSIS OF STUDY

This study generated and evaluated extensive data on the Quabbin and Wachusett Reservoirs and the Connecticut and Millers Rivers systems, with the objective of making predictions on the impacts of diverting portions of these riverine systems into Quabbin Reservoir. New England Research, Inc. was charged with overall responsibility for the study, and was assisted by Alden Research Laboratories of Worcester Polytechnic Institute, Clark University, Mason Research Institute, University of Massachusetts, and Worcester Polytechnic Institute.

Field and laboratory data included approximately 100 parameters, including biological, chemical, physical, and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information, and pollution abatement plans were considered and evaluated. Finally, other pertinent data available from both public and private sources, especially on the Connecticut River, were evaluated in the light of the objectives of this study.

Central to the evaluation was the development of a qualitative conceptual model of reservoir dynamics. If water of lower quality is introduced from a donor system into a receiver system, there will most likely be a loss in water quality in the receiver system. This loss of water quality is due to various materials in the water. These materials include molecules,

ions, suspended inorganic materials, organic debris, and living organisms. The fates of these materials are varied and complex, and include evaporation, transfer, transformation and deposition. These possible pathways are not mutually exclusive; for example, a DDT molecule could take all four pathways. What happens to the various materials is a function of many mechanisms. One of the central problems of ecology today is to trace the flow of materials from the various compartments of an ecosystem. While our model cannot be viewed as a quantitative model, it is nevertheless a useful qualitative model with which to begin making predictions as to changes in water quality brought about by the proposed diversions, as required by this study.

Dilution of riverine waters by ambient reservoir volume alone will probably not be sufficient to insure an acceptable water quality in Quabbin Reservoir. However, fallout of suspended materials and the "treatment plant" capacity of Quabbin Reservoir are expected to result in an acceptable water quality.

General predictions were made on the impacts of the proposed diversions on Quabbin Reservoir. Potential impacts have both public health and general environmental significance. The potential magnitude of a given impact upon Quabbin Reservoir is generally higher with the proposed Connecticut River diversion than with the proposed Millers (Tully) River system diversion. As a convenience in making evaluations of the probable impacts of the proposed diversions, the period 1972-2000 was divided into four phases. Phase I,

(1972-1976) is the period before diversion of the Connecticut River. The volume of Quabbin Reservoir will decline during this period. Phase II (1976-1980) represents the period from the beginning of the Connecticut River diversion to the time when the Tully River diversion becomes operative. The reservoir volume will increase during this period. The period 1980-1989 (Phase III) represents a period when both diversions are operative, and the reservoir volume continues to increase. During the final phase (Phase IV, 1989-2000) both diversions continue to be operative but reservoir volume declines.

The greatest potential for both ecological and public health impacts on Quabbin Reservoir is seen to exist with Phase II. Phase III will probably be associated with a general improvement in water quality. Because of declining reservoir volumes, Phases I and IV will show some deterioration of water quality in the reservoir.

Impacts on the proposed donor systems will vary in magnitude. No significant impacts on the hydrology, water quality, or general ecology of the Connecticut River are predicted. On the other hand, some changes in hydrology, water quality and general ecology can be expected in the Millers River system. These changes will result mainly from the reduction in water flow volume and the creation of impoundments. However, some of the long term impacts will be reduced as the proposed state-federal secondary treatment cleanup of the Millers River is implemented.

A no-diversion alternative was also considered in this study. Assuming present projections on water supply and water demand, Quabbin Reservoir will have exhausted its supply by 1985. However, before that time, the general condition of the reservoir will have deteriorated to the point where it will cease to be an acceptable public water supply. Therefore, we view the no-diversion alternative as unrealistic, unless other alternatives, outside the scope of the present study can solve the projected water supply problem for Metropolitan Boston.

Related to no diversion are any delays in proposed diversions. We view Phase I (1972-1976) as a particularly sensitive period because of the continued loss of water volume in Quabbin Reservoir. This loss in water volume will increase the risks for negative impacts from the riverine diversions. Therefore, delays in diversion for only a few years will probably result in greater impacts on the reservoir.

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1. INTRODUCTION

The objectives of the research activities which are the basis of this report are as follows:

> to acquire and interpret information and data that will permit judgments as to the probable long- and short-range effects of the proposed diversions of water from the Millers River and certain of its tributaries, and from portions of the Connecticut River into Quabbin Reservoir on (1) the quality of public water supplies to be stored in Quabbin and Wachusett Reservoirs, and (2) the ecological relationships in the donor systems and in the receiving reservoir systems.

The geographical relationships of these systems are shown in the frontispiece.

Data and information acquired and considered in the progress of this study include that which was (1) provided to New England Research, Inc. by the two sponsoring agencies: the U. S. Army Corps of Engineers and the Metropolitan District Commission, (2) collected by New England Research from other agencies, personal contacts, and published literature, and (3) generated by New England Research and its subcontractors. Data and information included in the first two categories above are referenced in Appendix 4. Data from the third category include measurements of the following parameters:

(1) Physical Parameters

Temperature, dissolved oxygen, color, specific conductance, odor, pH, turbidity.

(2) Biological Parameters

a. Phytoplankton (numbers and types; 11 field categories of algal types)

b. Bacteria (numbers and types; 5 groups of bacteria)

c. Planktonic and benthic animals (numbers and types; 22 groups of animals)

(3) Chemical Parameters

a. Pesticides (concentrations of 13 individual pesticides or pesticide classes)

b. Inorganic chemistries (concentrations of 38 individual chemical species)

The frequencies with which these parameters were measured and the locations of sampling stations will be found in Section 3.

In addition to data generated in the above analyses, hydrodynamic data for Quabbin Reservoir were generated by means of a scale model of Quabbin Reservoir (25' long x 11' wide) which was constructed and tested by the Alden Research Laboratories of Worcester Polytechnic Institute, Holden, Massachusetts.

The volume of raw data generated in this study is obviously large; it consists of 32,000 information bits on over 2500 pages. It cannot be presented in its totality in this report without subverting the purpose of this report; namely, to present in as clear and concise a manner as possible those judgments required by the objectives of the study. This report therefore contains compilations and reductions of raw data which are particularly useful to the discussion of scientific issues which have to be dealt with under the study objectives. Compilations and reductions of data contained in this report are based on data collected from

December 1970 through September 30, 1971. A supplementary report of data collected from October 1 through November 30, 1971 (Fourth Quarter) has also been compiled and appears in Appendix 6.

The scientific issues which are considered in this report as being essential to the study objectives derive from a qualitative model of diversion which is based upon the following working assumptions:

(1) A reservoir such as Quabbin Reservoir may be viewed as a treatment plant which operates at or close to a steady state so as to produce output water which is of a higher quality than that of the average input water which supplies the reservoir. There are dynamic seasonal changes which tend to displace the steady state, but in terms of a year or several years the reservoir can be viewed as coming back to a dynamic equilibrium.

(2) Inputs into a reservoir other than those already operative while the reservoir is in a steady state will alter the dynamics of the system and, hence, will influence any mechanisms underlying the "treatment plant" capability as discussed above.

(3) Such new inputs into a reservoir, if they contain waters of significantly lower quality than that of on-going inputs, will tend to put a heavier stress on the treatment capacity of the reservoir for some indefinite period of time.

(4) The concept of a "reserve treatment capacity" of the reservoir is central to the question of how much of an additional stress the reservoir can tolerate without a drastic change in water quality. Any assessment of short-term and long-term effects, both public health and ecological, must focus on this concept.

(5) The specific rate of change of treatment efficiency, its persistence and recovery, and the efficiency of the eventually achieved new steady state is a complex function of the ecological relationships disrupted, modified, or introduced by the additional inputs into the reservoir.

The generalized qualitative model is depicted in Figure 1. In this diagram a single diversion period is shown, with representations of the consequent loss in water quality (ΔQL) and recovery in water quality (ΔQR). An important point of this model is that the "fallout" of whatever contributes to the incremental loss of water quality (ΔQL) does not necessarily follow a logarithmic decay, as with many physical phenomena. Indeed the water quality recovery (ΔQR) is governed by a complex of factors, and in some instances there could be a further deterioration after time T_2 without an additional input.

A number of cases of this generalized model, as it can be applied to the contemplated yearly diversions into Quabbin Reservoir, are possible. Three of these cases are as follows:

Case I:	$\Delta QL =$	ΔQR for all diversion cycles
Case II:	$\Delta QL =$	ΔQR at end of first diversion cycle
	$\Delta QL >$	ΔQR for subsequent diversion cycles
Case III.	$\Delta QL >$	ΔQR for all diversion cycles

These three cases of the generalized model are depicted in Figure 2. Other cases are developed in Section 8 of this report.

The essential qualitative nature of this model cannot be overemphasized. The concept of water quality itself, for example, cannot be quantified without reference

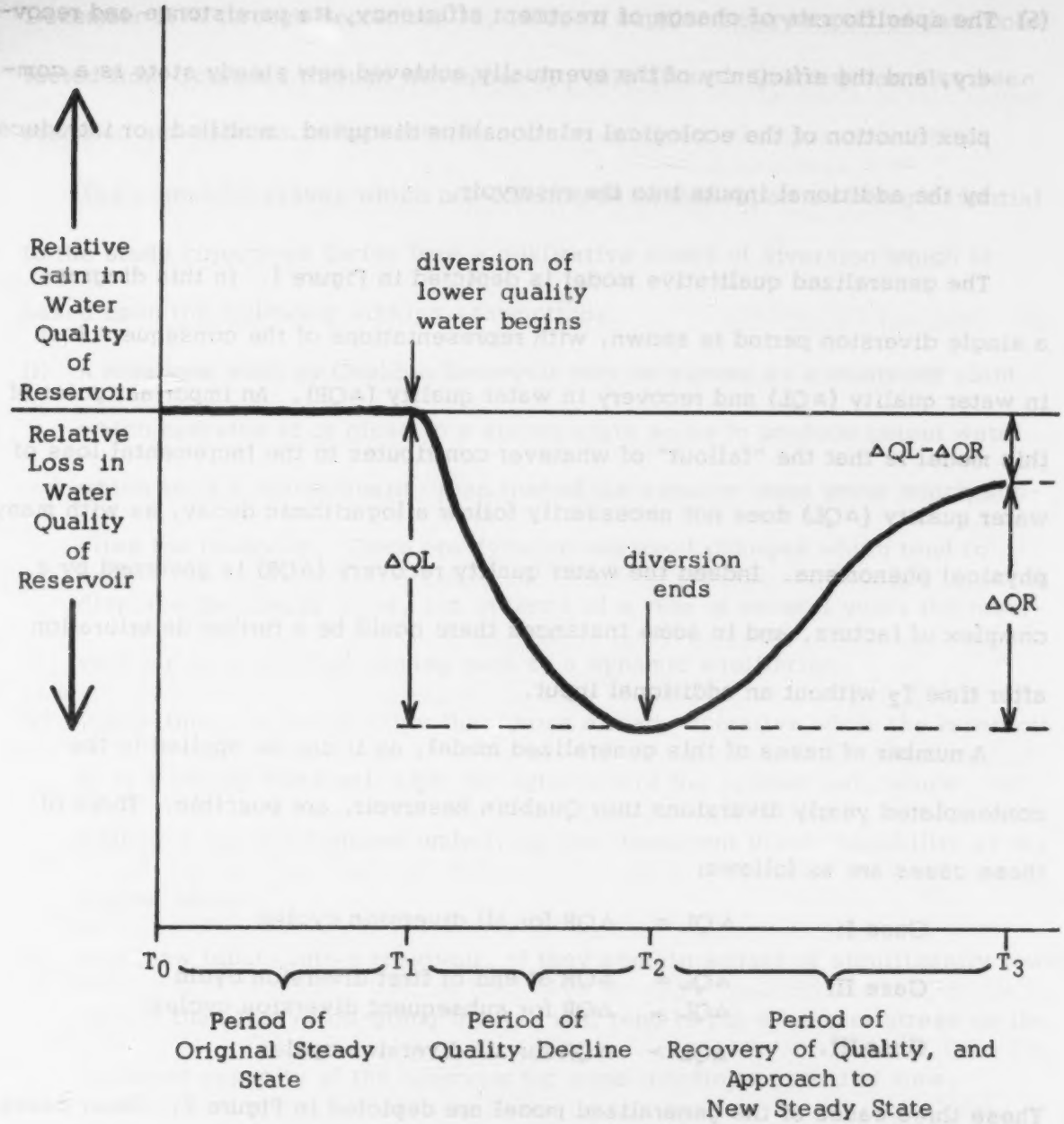

Figure 1. Generalized Qualitative Model of Diversion

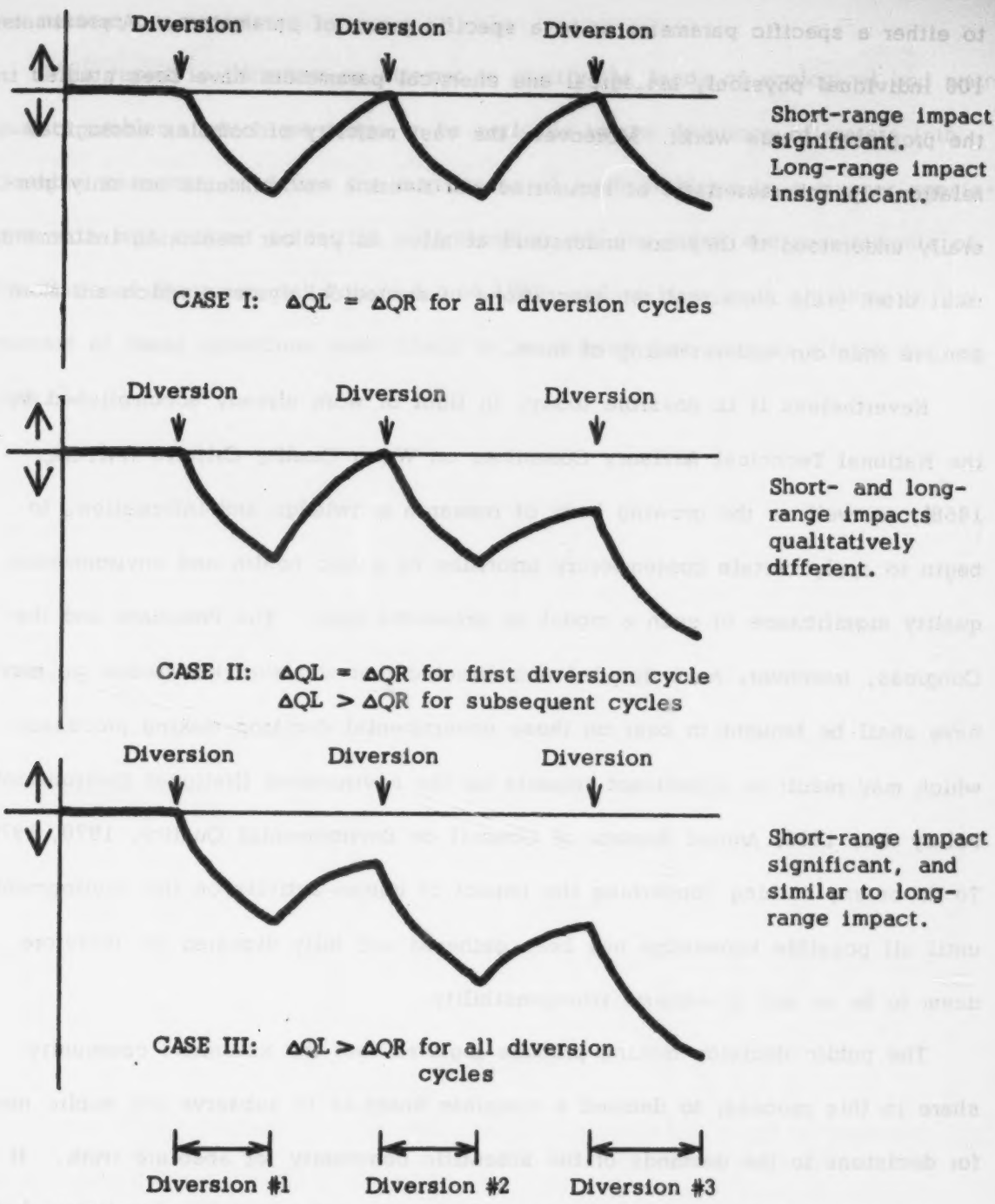

Figure 2. Three Cases of Generalized Model of Diversion

to either a specific parameter or to a specific group of parameters. Approximately 100 individual physical, biological and chemical parameters have been studied in the progress of this work. Moreover, the vast majority of complex ecological relationships characteristic of lacustrine and riverine environments are only generally understood if they are understood at all. As yet our measuring instruments most often yield numerical representations of ecological systems which are more precise than our understanding of them.

Nevertheless it is possible today, in light of work already accomplished by the National Technical Advisory Committee on Water Quality Criteria (FWPCA. 1968), as well as the growing body of research knowledge and information, to begin to apply certain contemporary priorities of public health and environmental quality significance to such a model as presented here. The President and the Congress, moreover, have decided and directed that whatever knowledge we may have shall be brought to bear on those governmental decision-making processes which may result in significant impacts on the environment (National Environmental Policy Act, 1969; Annual Reports of Council on Environmental Quality, 1970, 1971). To do or say nothing concerning the impact of human activity on the environment until all possible knowledge has been gathered and fully digested we therefore deem to be an act of extreme irresponsibility.

The public decision-making process requires that the scientific community share in this process; to demand a complete study is to subserve the public need for decisions to the demands of the scientific community for absolute truth. It is in this spirit of interplay between public needs and scientific objectivity that

we present our report.

This report is therefore an attempt to clarify the kinds of ecological and water quality problems which we judge to be probable in the diversion of waters into Quabbin Reservoir; to define the magnitudes of such problems in a manner consistent with both current scientific understanding and the spirit and requirements of the National Environmental Policy Act of 1969; and to view such problems in the context of those situations most likely to be derived from various alternative actions.

2. DESCRIPTION OF PROPOSED DIVERSIONS

A. Connecticut River

It is proposed to divert some Connecticut River water to Quabbin Reservoir during freshet flow. The diversion is conditioned by a flow in the Connecticut River of 17,000 cfs (cubic feet/second) or greater as measured at the U.S.G.S. gauging station at Montague City, Massachusetts.

The diversion (Figure 3) will be effected by pumping waters from the Connecticut River to the existing Northfield Mountain Pumped Storage Reservoir at an elevation of 1004.5 feet at full pool.[1] At Northfield Reservoir an intake tower will be built to take water from near the bottom of the dam (elevation 923 feet) through fish-screened sluice gates into an 8-foot diameter pipe under the dam. This water will then be conveyed through a proposed 10-mile underground tunnel to the vicinity of Rattlesnake Hill (elevation 838 feet). From the outlet of the tunnel, water would enter the northern end of the central arm of Quabbin Reservoir.

The rate of diversion would be 375 MGD (million gallons/day) with a capacity of up to 500 MGD. An anticipated average 70-day diversion period,

---

[1]The Connecticut Light and Power Company, The Hartford Electric Light Company, Western Massachusetts Electric Company, Drawing: Diversion Intake Works, Quabbin Water Diversion Facility, Northfield Mountain Pumped Storage Project F.P.C. Project No. 2485.

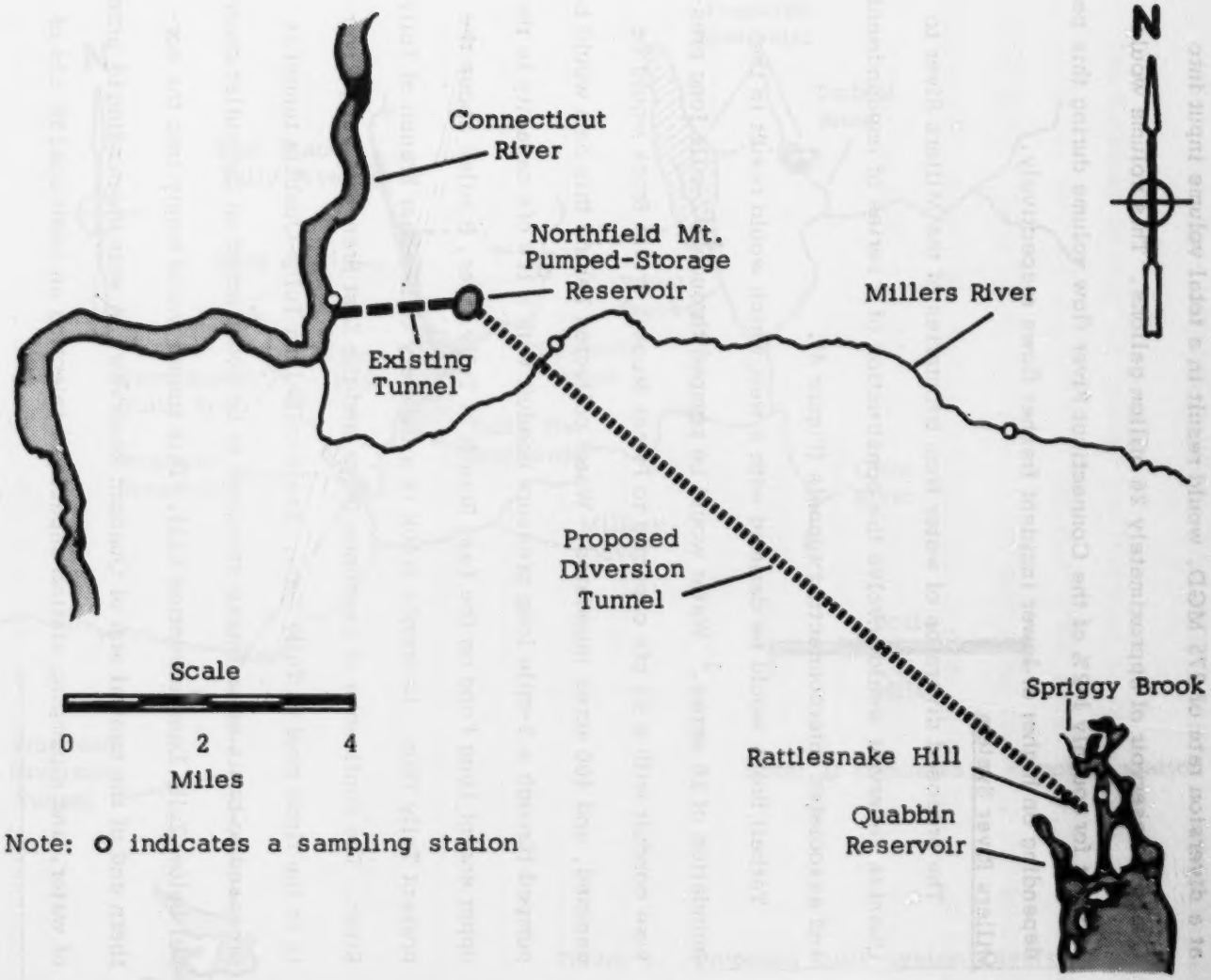

Figure 3. Proposed Connecticut River Diversion

at a diversion rate of 375 MGD, would result in a total volume input into Quabbin Reservoir of approximately 26 billion gallons. This volume would account for roughly 1-2% of the Connecticut River flow volume during this period, depending on higher or lower incident freshet flows respectively.

B. Millers River System

The proposed diversion of water from tributaries of the Millers River to Quabbin Reservoir would involve the construction of a series of impoundments and associated interconnecting tunnels (Figure 4).

Tarbell Brook would be dammed with a weir which would result in the inundation of 28 acres.[1] Water would be pumped through a 2-mile long pressure conduit with a 90 cfs capacity to Priest Brook. Priest Brook would be dammed, and 400 acres inundated. Water collected behind this dam would be pumped through a 5-mile long pressure conduit with a 120 cfs capacity to the upper end of Long Pond on the East Branch of Tully River, 3 miles above the present Tully Dam. Lawrence Brook is a tributary of the East Branch of Tully River. The confluence of Lawrence Brook and the East Branch of Tully River is in the flood pool of Tully Dam. The 9-mile long Tully-Quabbin tunnel is proposed to begin at an intake structure to be constructed on the outlet channel below Tully Dam (elevation 625). This tunnel would empty into the northern end of the central arm of Quabbin Reservoir. A weir impounding 13 acres of water, and a pumping station capable of injecting an additional 90 cfs of

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[1] Data on impoundment areas and capacities added to drawing entitled: Northeastern United States Water Supply Study, Tully Dam Diversion, Millers River Basin, Massachusetts. New England Division, Corps of Engineers, U. S. Army.

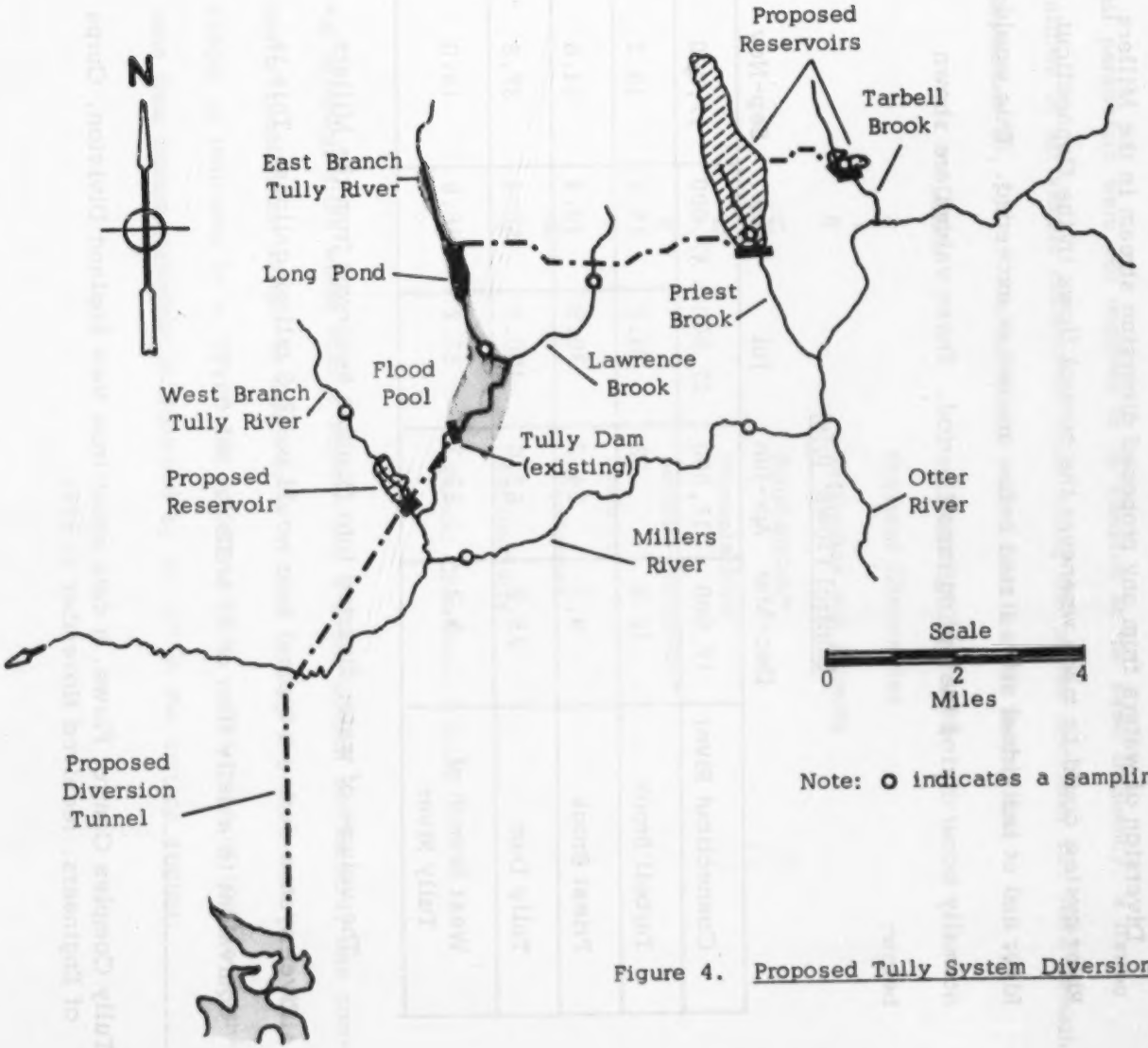

Figure 4. Proposed Tully System Diversion

water into the tunnel would be constructed at the intercept of the Tully-Quabbin tunnel with the West Branch of Tully River.

Diversion of waters from any proposed diversion stream in the Millers River system could be made whenever the control flows in the Connecticut River and at individual sites listed below are met or exceeded. This would normally occur during the spring runoff period. These values are shown below:

Control Flows[1] (cfs)

	Dec-Mar	Apr-Jun	Jul	Aug	Sep-Nov
Connecticut River	17,000	17,000	17,000	17,000	17,000
Tarbell Brook	12.8	32	51.2	25.6	19.2
Priest Brook	9.7	24.3	38.8	19.4	14.6
Tully Dam	25.2	63.0	100.8	50.4	37.8
West Branch of Tully River	9.2	23.3	37.2	18.6	14.0

The volume of water diverted into Quabbin Reservoir from the Millers River system during a typical year would be 17.5 billion gallons. This is equivalent to a daily flow of 48 MGD for 365 days.

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[1] Tully Complex Control Flows, a data sheet from New England Division, Corps of Engineers, received November 3, 1971.

3. SAMPLING STATIONS AND FREQUENCIES

The locations of sampling stations are indicated on Figures 5, 6 and 7. Since all parameters were not required to be sampled at the same frequency, a listing follows of all sample collections made during the period December 22, 1970 through September 30, 1971. The parameter codes used in that listing are:

Code	Parameters Measured
A	Physical Chemistries
B	Pesticides and Phenols
C	Zooplankton*
D	Phytoplankton
E	Benthic Organisms*
F	Bacteria
G	Chemistries
R	Radioactivity
X	Carbon Chloroform Extract

*At reservoir sites where both a surface and a depth station are located, one composite zooplankton sample is taken by a vertical tow of the Wisconsin net. This sample is indicated by a "C" at the surface station. Collection of benthic organisms from bottom materials is indicated by an "E" at the surface station.

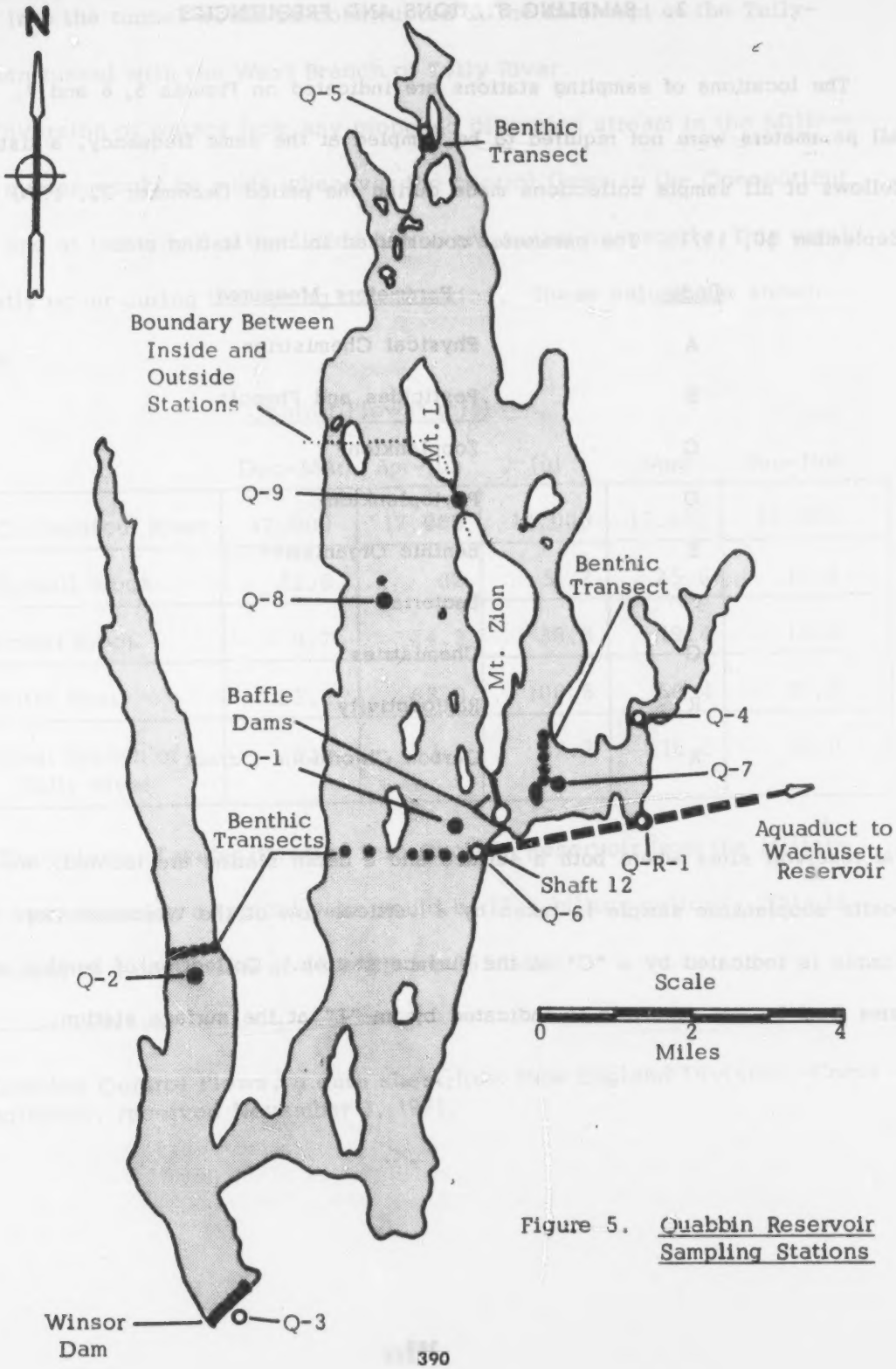


Figure 5. Quabbin Reservoir Sampling Stations

59-652 O - 80 - Vol.1 - 28

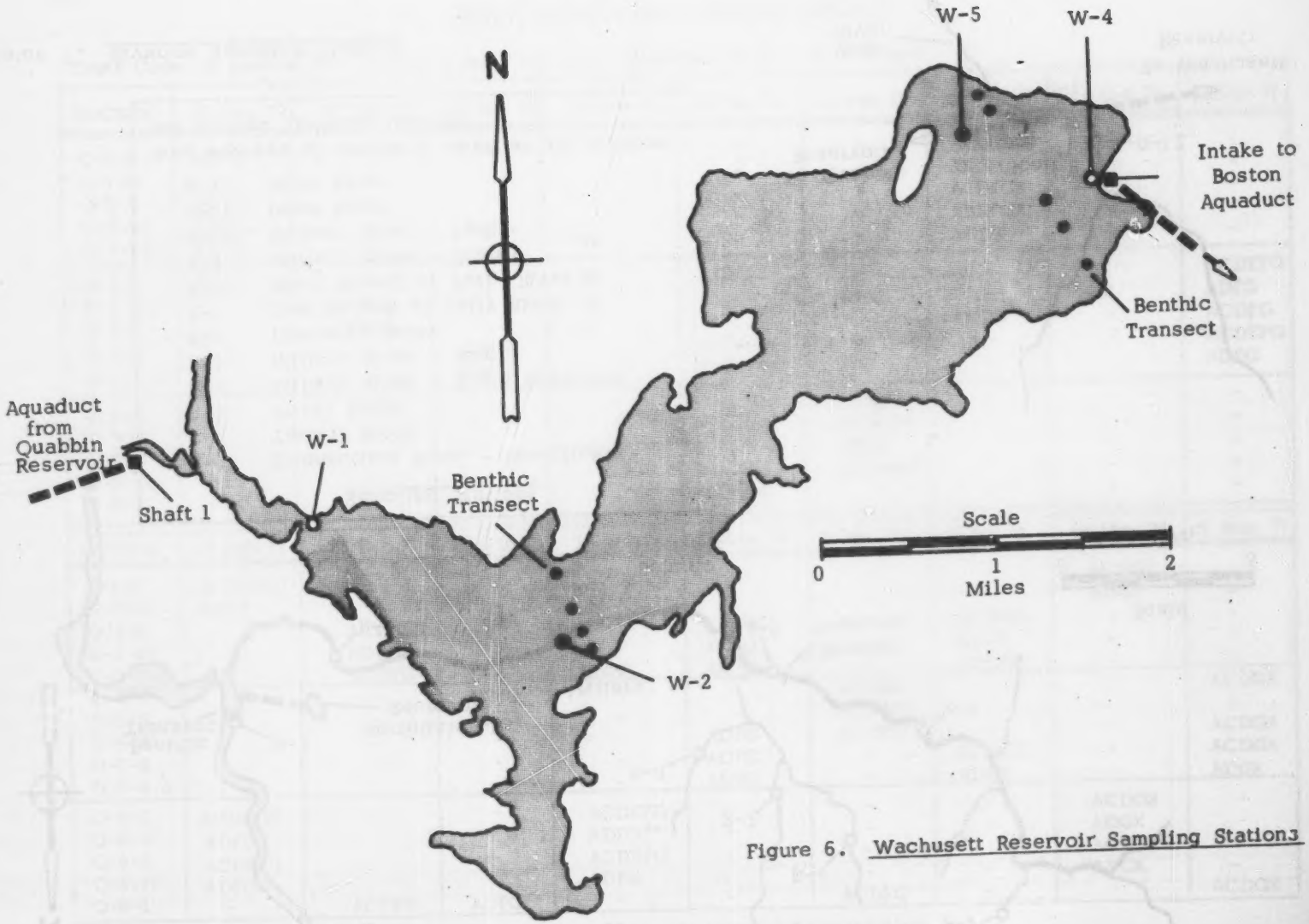
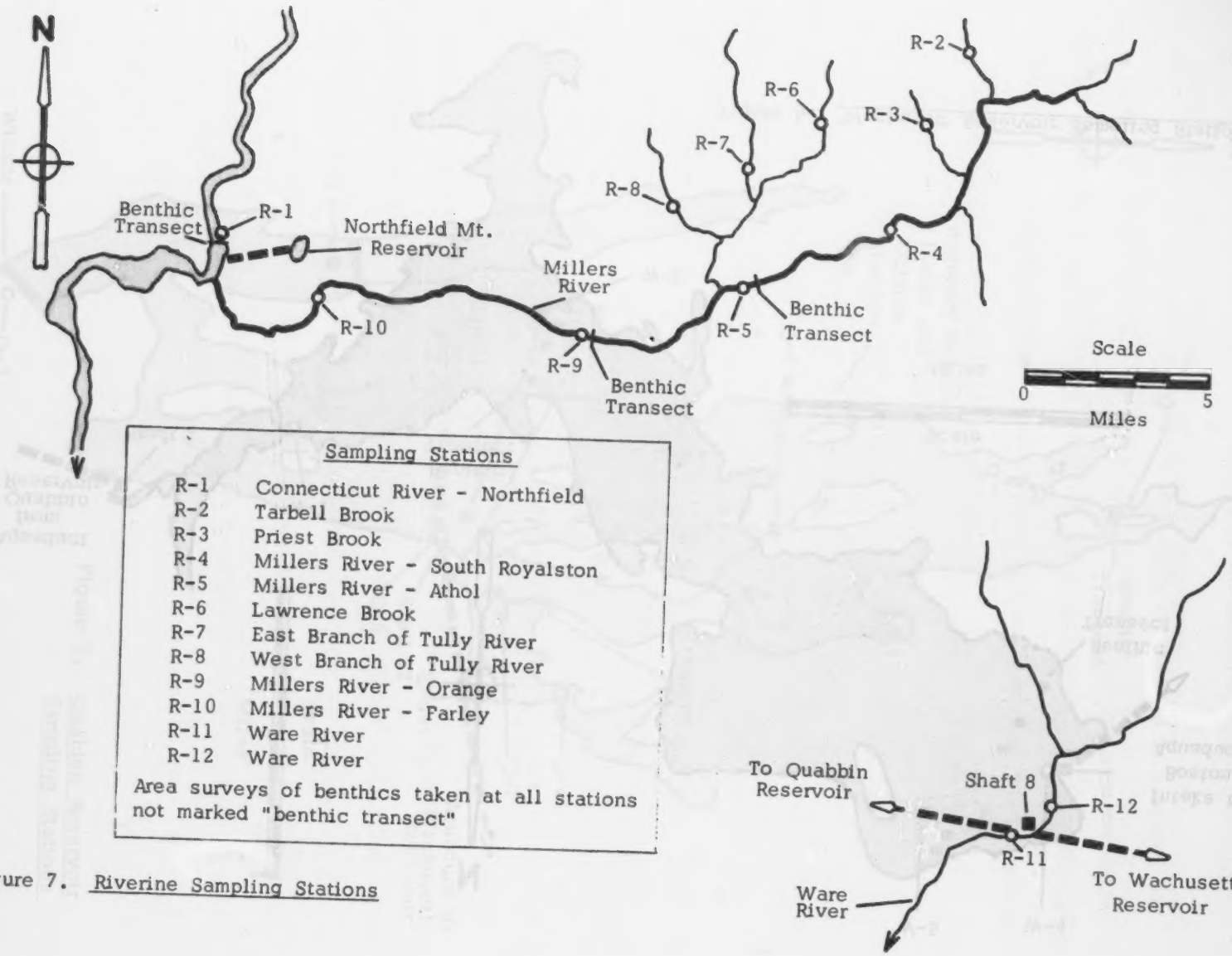


Figure 6. Wachusett Reservoir Sampling Stations



Sampling Stations

R-1	Connecticut River - Northfield
R-2	Tarbell Brook
R-3	Priest Brook
R-4	Millers River - South Royalston
R-5	Millers River - Athol
R-6	Lawrence Brook
R-7	East Branch of Tully River
R-8	West Branch of Tully River
R-9	Millers River - Orange
R-10	Millers River - Farley
R-11	Ware River
R-12	Ware River

Area surveys of benthics taken at all stations not marked "benthic transect"

Figure 7. Riverine Sampling Stations

SAMPLE COLLECTIONS - QUABBIN RESERVOIR

Depth Code: S-surface; 10 - 10 meters; tap - sink tap in powerhouse; 6.5 - 6.5 meters

STATION	22 Dec 70	07 Jan 71	20 Jan 71	25 Jan 71	01 Feb 71	02 Feb 71	03 Feb 71	22 Feb 71	24 Feb 71
Q-1-S	ADFG	-	-	-	-	-	ABDFGX	-	-
Q-1-10	-	-	-	-	-	-	ABDFGX	-	-
Q-2-S	ADFG	-	-	-	-	-	ABDFGX	-	-
Q-2-10	ADFG	-	-	-	-	-	ABDFGX	-	-
Q-3-Tap	ADFG	-	-	BX	-	-	ADFG	-	-
Q-4-S	ADFG	-	-	BX	ADFG	-	-	-	ACDEFG
Q-5-S	-	ADFG	-	BX	-	ADFG	-	CE	ADFG
Q-6-S	-	ADFG	-	BX	-	-	ADFG	-	ACDFG
Q-7-S	-	-	ADFG	-	ABDFGX	-	-	-	ACDEFG
Q-7-6.5	-	-	ADFG	-	ABDFGX	-	-	-	ADFG
Q-8-S	-	-	-	-	-	ABDFGX	-	-	-
Q-8-10	-	-	-	-	-	ABDFGX	-	-	-
Q-9-S	-	-	-	BX	-	ADFG	-	-	-
Q-9-10	-	-	-	-	-	ABDFGX*	-	-	-
Q-R-1	-	-	-	-	ABDFGX	-	-	-	-

STATION	25 Feb 71	25 Feb 71	24 Mar 71	25 Mar 71	26 Mar 71	14 Apr 71	15 Apr 71	04 May 71	05 May 71
Q-1-S	ACDEFG	-	-	ACDEFG	-	-	-	ACDGX	-
Q-1-10	ADFG	-	-	ADFG	-	-	-	ADGX	-
Q-2-S	-	ACDEFG	-	-	ADFG	-	ACDFG	-	-
Q-2-10	-	ADFG	-	-	ADFG	-	ADFG	-	-
Q-3-Tap	-	ACDFG	-	-	ADFG	-	ACDFG	-	-
Q-4-S	-	-	ADFG	-	-	ACDFG	-	-	ACDGX
Q-5-S	-	-	ADFG	-	-	ACDEFG	-	-	-
Q-6-S	-	-	-	-	ADFG	ACDFG	-	-	ACDGX
Q-7-S	-	-	-	-	ADFG	-	ACDFG	-	ACDGX
Q-7-6.5	-	-	-	-	ADFG	-	ADFG	-	ADGX
Q-8-S	ACDEFG	-	-	ACDEFG	-	-	-	ACDGX	-
Q-8-10	ADFG	-	-	ADFG**	-	-	-	ADGX	-
Q-9-S	ACDEFG	-	-	ACDEFG	-	-	-	ACDGX	-
Q-9-10	ADFG	-	-	ADFG	-	-	-	ADGX	-
Q-R-1	-	ACDFG	ADFG	-	-	ACDFG	-	-	ACDGX

* Sample taken at 3 meters depth.

** Sample taken at 8 meters depth.

SAMPLE COLLECTIONS - QUABBIN RESERVOIR

STATION	06 May 71	18 May 71	19 May 71	20 May 71	01 Jun 71	02 Jun 71	03 Jun 71	15 Jun 71	16 Jun 71
Q-1-S	-	ABCDEFG	-	-	ACDFG	-	-	ACDFG	-
Q-1-10	-	ABDFG	-	-	ADFG	-	-	ADFG	-
Q-2-S	ACDGX	-	-	ABCDFG	-	-	ACDFG	-	-
Q-2-10	ADGX	-	-	ABDFG	-	-	ADFG	-	-
Q-3-Tap	ACDGX	-	-	ABCDFG	-	-	ACDFG	-	-
Q-4-S	-	-	ABCDFG	-	-	ACDFG	-	-	ACDFG
Q-5-S	ACDGX	-	-	ABCDFG	-	-	ACDFG	-	-
Q-6-S	-	-	ABCDFG	-	-	ABCDFG	-	-	ACDFG
Q-7-S	-	-	ABCDEFG	-	-	ACDFG	-	-	ACDFG
Q-7-6.5	-	-	ABDFG	-	-	ADFG	-	-	ADFG
Q-8-S	-	ABCDFG	-	-	ACDFG	-	-	ACDFG	-
Q-8-10	-	ABDFG	-	-	ADFG	-	-	ADFG	-
Q-9-S	-	ABCDFG	-	-	ACDFG	-	-	ACFG	D
Q-9-10	-	ABDFG	-	-	ADFG	-	-	ADFG	-
Q-R-1	-	-	ABCDFG	-	-	-	-	-	-

STATION	17 Jun 71	29 Jun 71	30 Jun 71	01 Jul 71	12 Jul 71	19 Jul 71	20 Jul 71	21 Jul 71	22 Jul 71
Q-1-S	-	ACDFG	-	-	E	-	ACDFGR	-	-
Q-1-10	-	ADFG	-	-	-	-	ADFGR	-	-
Q-2-S	ACDFG	-	-	ACDFG	-	E	-	-	ACDFGR
Q-2-10	ADFG	-	-	ADFG	-	-	-	-	ADFGR
Q-3-Tap	ACDFG	-	-	ACDFG	-	-	-	-	ACDFGR
Q-4-S	-	-	ACDFG	-	-	-	-	ACDFGR	-
Q-5-S	ACDEFG	-	-	ACDFG	-	E	-	-	ACDFGR
Q-6-S	-	-	ACDFG	-	-	-	-	ACDFGR	-
Q-7-S	-	-	ACDFG	-	E	-	-	ACDFGR	-
Q-7-6.5	-	-	ADFG	-	-	-	-	ADFGR	-
Q-8-S	-	ACDFG	-	-	-	-	ACDFGR	-	-
Q-8-10	-	ADFG	-	-	-	-	ADFGR	-	-
Q-9-S	-	ACDFG	-	-	-	-	ACDFGR	-	-
Q-9-10	-	ADFG	-	-	-	-	ADFGR	-	-
Q-R-1	-	-	-	-	-	-	-	-	-

* 27 May Q-2, E

SAMPLE COLLECTIONS - QUABBIN RESERVOIR

STATION	17 Aug 71	18 Aug 71	19 Aug 71	14 Sep 71	15 Sep 71	16 Sep 71	20 Sep 71	27 Sep 71
Q-1-S	ABCDFGX	-	-	ACDG	-	-	E	-
Q-1-10	ABDFGX	-	-	ADG	-	-	-	-
Q-2-S	-	-	ABCDFGX	-	-	ACDFG	-	E
Q-2-10	-	-	ABDFGX	-	-	ADFG	-	-
Q-3-Tap	-	-	ABCDFGX	-	-	ACDFG	-	-
Q-4-S	-	ABCDFGX	-	-	ACDFG	-	-	-
Q-5-S	-	-	ABCDFGX	-	-	ACDFG	-	E
Q-6-S	-	ABCDFGX	-	-	ACDFG	-	-	-
Q-7-S	-	ABCDFGX	-	-	ACDFG	-	E	-
Q-7-6.5	-	ABDFGX	-	-	ADFG	-	-	-
Q-8-S	ABCDFGX	-	-	ACDG	-	-	-	-
Q-8-10	ABDFGX	-	-	ADG	-	-	-	-
Q-9-S	ABCDFGX	-	-	ACDG	-	-	-	-
Q-9-10	ABDFGX	-	-	ADG	-	-	-	-
Q-R-1	-	-	-	-	-	-	-	-

SAMPLE COLLECTIONS - WACHUSETT RESERVOIR

STATION	29 Dec 70	20 Jan 71	26 Jan 71	27 Jan 71	28 Jan 71	29 Jan 71	04 Feb 71	18 Feb 71	01 Mar 71
W-1-S	ADFG	-	BX	ADFG	E	-	-	C	ACDFG
W-2-S	ADFG	-	-	-	-	ABDFGX	F	CE	ACDFG
W-2-10	ADFG	-	-	-	-	ABDFGX	F	-	ADFG
W-4-S	ADFG	-	BX	ADFG	-	-	-	C	ACDFG
W-5-S	-	ADFG	-	ABDFGX	-	-	-	CE	ACDFG
W-5-10	-	ADFG*	-	ABDFGX	-	-	-	-	ADFG
W-3-S	ADFG	-	-	-	-	-	-	-	-
W-4-S	ADFG	-	-	-	-	-	-	-	-

STATION	29 Mar 71	16 Apr 71	29 Apr 71	13 May 71	27 May 71	10 Jun 71	24 Jun 71	06 Jul 71	15 Jul 71
W-1-S	ACDFG	ACDFG	ADG	ACDFGX	ABCDFG	ACDFG	ACDFG	-	ACDFGR
W-2-S	-	ACDFG	ADG	ACDEFGX	ABCDFG	ACDFG	ACDFG	E	ACDFGR
W-2-10	-	ADFG	ADG	ADFGX	ABDFG	ADFG	ADFG	-	ADFGR
W-4-S	ACDFG	ACDFG	ADG	ACDFGX	ABCDFG	ACDFG	ACDFG	-	ACDFGR
W-5-S	ACDEFG	ACDFG	ADG	ACDEFGX	ABCDFG	ACDFG	ACDFG	E	ACDFGR
W-5-10	ADFG	ADFG	ADG	ADFGX	ABDFG	ADFG	ADFG	-	ADFGR

STATION	12 Aug 71	07 Sep 71	09 Sep 71						
W-1-S	ABCDFGX	-	ACDFG						
W-2-S	ABCDFGX	E	ACDFG						
W-2-10	ABDFGX	-	ADFG						
W-4-S	ABCDFGX	-	ACDFG						
W-5-S	ABCDFGX	E	ACDFG						
W-5-10	ABDFGX	-	ADFG						

*Sample taken at 6.5 meters depth.

SAMPLE COLLECTIONS - RIVERINE STATIONS

STATION	30 Dec 70	06 Jan 71	19 Jan 71	26 Jan 71	28 Jan 71	29 Jan 71	01 Feb 71	04 Feb 71	10 Feb 71
R-1	ADFG	-	-	BX	-	ADFG	-	-	CE
R-2	-	ADFG	-	BX	ADFG	-	-	E	-
R-3	-	ADFG	-	BX	ADFG	-	-	E	-
R-4	-	ADFG	-	-	-	ADFG	-	-	-
R-5	-	ADFG	-	BX	-	ADFG	-	-	-
R-6	-	ADFG	-	-	ADFG	-	-	E	-
R-7	-	ADFG	-	BX	ADFG	-	-	E	-
R-8	-	ADFG	-	BX	ADFG	-	-	E	-
R-9	ADFG	-	-	-	-	ADFG	-	-	CE
R-10	ADFG	-	-	-	-	ADFG	-	-	CE
R-11	ADFG	-	E	-	-	-	ADFG	-	-
R-12	ADFG	-	E	-	-	-	ADFG	-	-

STATION	16 Feb 71	26 Feb 71	02 Mar 71	03 Mar 71	16 Mar 71	19 Mar 71	22 Mar 71	23 Mar 71	24 Mar 71
R-1	-	-	ADFG	-	-	-	ADFG	-	-
R-2	C	-	-	ADFG	CE	-	-	ADFG	-
R-3	C	-	-	ADFG	CE	-	-	ADFG	-
R-4	CE	-	ADFG	A	-	-	ADFG	-	-
R-5	E	-	ADFG	A	-	-	ADFG	-	-
R-6	C	-	-	ADFG	-	-	-	ADFG	-
R-7	C	-	-	ADFG	-	-	-	ADFG	-
R-8	C	-	-	ADFG	-	-	-	ADFG	-
R-9	-	-	ADFG	-	-	-	ADFG	-	-
R-10	-	-	ADFG	-	-	-	ADFG	-	-
R-11	-	ADFG	-	-	-	C	-	-	ADFG
R-12	-	ADFG	-	-	-	C	-	-	ADFG

SAMPLE COLLECTIONS - RIVERINE STATIONS

STATION	31 Mar 71	05 Apr 71	08 Apr 71	12 Apr 71	13 Apr 71	14 Apr 71	21 Apr 71	22 Apr 71	27 Apr 71
R-1	-	-	C	ACDFG	-	-	-	X	-
R-2	-	-	-	-	ACDFG	-	X	-	ADG
R-3	-	-	-	-	ACDFG	-	X	-	ADG
R-4	C	E	-	ACDFG	-	-	X	-	ADG
R-5	-	CE	-	ACDFG	-	-	X	-	-
R-6	CE	-	-	-	ACDFG	-	X	-	ADG
R-7	CE	-	-	-	ACDFG	-	X	-	ADG
R-8	C	-	-	-	ACDFG	-	X	-	ADG
R-9	-	C	-	ACDEFG	-	-	-	X	-
R-10	-	CE	-	ACDFG	-	-	-	X	-
R-11	-	-	-	-	-	ACDFG	-	X	-
R-12	-	-	-	-	-	ACDFG	-	X	-

STATION	28 Apr 71	11 May 71	12 May 71	25 May 71	26 May 71	08 Jun 71	09 Jun 71	22 Jun 71	23 Jun 71
R-1	ADG	-	ACDFG	-	ABCDFG	-	ACDFG	-	ACDFG
R-2	-	ACDG	-	ABCDFG	-	ACDFG	-	ACDFG	-
R-3	-	ACDG	-	ABCDFG	-	ACDFG	-	ACDFG	-
R-4	-	ACDG	-	ACDFG	-	ACDFG	-	ACDFG	-
R-5	ADG	-	ACDFG	-	ABCDFG	-	ACDFG	-	ACDFG
R-6	-	ACDG	-	ACDFG	-	ACDFG	-	ACDFG	-
R-7	-	ACDG	-	ABCDFG	-	ACDFG	-	ACDFG	-
R-8	-	ACDG	-	ABCDFG	-	ACDFG	-	ACDFG	-
R-9	ADG	-	ACDFG	-	ACDFG	-	ACDFG	-	ACDFG
R-10	ADG	-	ACDFG	-	ACDFG	-	ACDFG	-	ACDFG
R-11	ADG	-	ACDFG	-	ACDFG	-	ACDFG	-	ACDFG
R-12	ADG	-	ACDFG	-	ACDFG	-	ACDFG	-	ACDFG

SAMPLE COLLECTIONS - RIVERINE STATIONS

STATION	08 Jul 71	13 Jul 71	14 Jul 71	15 Jul 71	26 Jul 71	02 Aug 71	04 Aug 71	10 Aug 71	11 Aug 71
R-1	E	-	ACDFG	R	-	-	-	-	ABCDFGX
R-2	-	ACDFG	-	R	E	-	-	ABCDFGX	-
R-3	-	ACDFG	-	R	E	-	-	ABCDFGX	-
R-4	-	ACDFG	-	R	-	-	E	ACDFGX	-
R-5	-	-	ACDFG	R	-	-	E	-	ABCDFGX
R-6	-	ACDFG	-	R	-	E	-	ACDFGX	-
R-7	-	ACDFG	-	R	-	E	-	ABCDFGX	-
R-8	-	ACDFG	-	R	-	-	-	ABCDEFGX	-
R-9	-	-	ACDFG	R	-	-	E	-	ACDFGX
R-10	-	-	ACDFG	R	-	-	-	-	ACDFGX
R-11	-	-	ACDFG	R	-	-	-	-	ACDFGX
R-12	-	-	ACDFG	R	-	-	-	-	ACDFGX

STATION	16 Aug 71	30 Aug 71	07 Sep 71	08 Sep 71					
R-1	-	-	-	ACDFG					
R-2	-	-	ACDFG	-					
R-3	-	-	ACDFG	-					
R-4	E	-	ACDFG						
R-5	-	-	-	ACDFG					
R-6	-	-	ACDFG						
R-7	-	-	ACDFG						
R-8	-	-	ACDFG	-					
R-9	-	-	-	ACDFG					
R-10	E	-	-	ACDFG					
R-11	-	E	-	ACDFG					
R-12	-	E	-	ACDFG					

* 23 Aug R-1, E

4. METHODOLOGY

Analytical methods for the various parameters were in keeping with the methods recommended in the United States Public Health Service, Drinking Water Standards (USPHS, 1962).

Many of the parameters are not covered in Drinking Water Standards (DWS) nor in Standard Methods for the Examination of Water and Wastewater (Standard Methods; APHA, 1971) recommended for analytical methods in DWS. In other instances only tentative procedures are suggested (e.g. chlorinated hydrocarbon pesticides). Finally, some of the sampling and analytical methods recommended in Standard Methods for macroinvertebrates had little relevance to some of the bottom substrates we encountered in some riverine stations.

Procedures followed in this study, then, were in keeping with Standard Methods and DWS. Changes were adopted to fit particular circumstances, usually after consultation with the MDC and the Corps of Engineers. Attempts were made to use the best methods available in the state-of-the-art, consistent with reasonable costs. Details in methodology are discussed in appropriate sections in the rest of this report and more extensively in Appendix 1.

5. RESULTS OF WATER QUALITY TESTS

A. Biological Data

(1) Bacteria

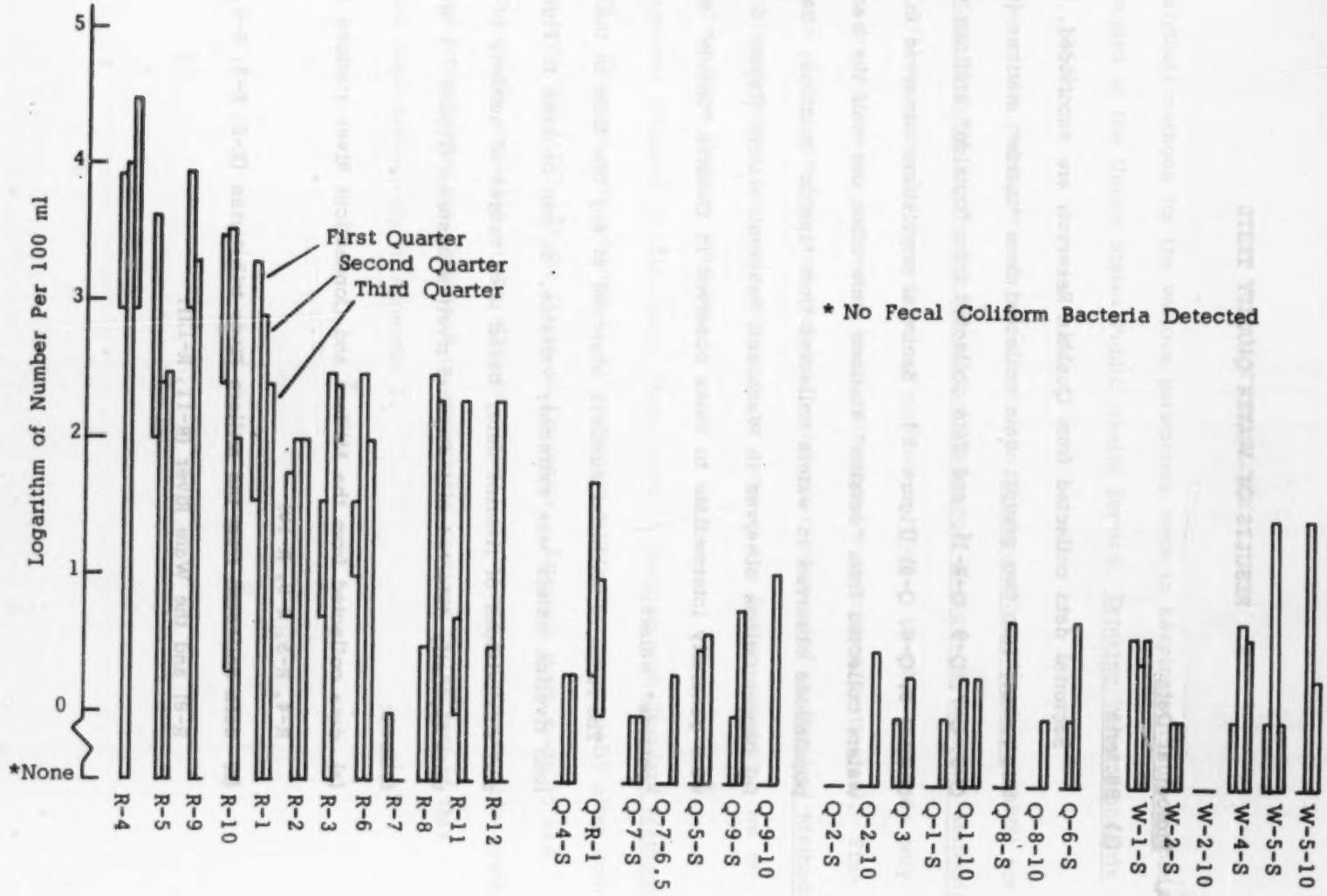
Bacterial data collected from Quabbin Reservoir are subdivided, in this report, into two groups: data collected from "inside" stations (Q-4, Q-5, Q-7, Q-9, Q-R-1), and data collected from "outside" stations (Q-1, Q-2, Q-3, Q-6, Q-8) (Figure 5). Bacterial populations observed in waters collected from "outside" stations were often one-half the bacterial populations observed in waters collected from "inside" stations. Bacterial concentrations observed in Wachusett Reservoir waters (Figure 6) were generally intermediate to those observed in Quabbin "inside" and "outside" waters.

The range of bacterial numbers observed at any one time in the various riverine waters was extremely variable, as can be seen in Figure 8; and subdivisions of riverine data, based upon ranges of numbers of bacteria typically detected in individual riverine systems (Figure 7) are as follows:

(a) data collected from the Millers and Connecticut River stations (R-1, R-4, R-5, R-9, R-10)

(b) data collected from the Millers River tributaries (R-2, R-3, R-6, R-7, R-8) and the Ware River (R-11, R-12).

Figure 8. Range of Fecal Coliform Bacteria for Each Station for the First Three Quarters, 1971



Bacterial concentrations in the Millers River tributaries and Ware River were generally comparable with concentrations observed in reservoir waters, while those in the Millers and Connecticut Rivers were significantly higher (Table 1).

The Connecticut River and Millers River system showed few changes in numbers of hetrotrophic bacteria over the first two quarters of the year and a general decrease in the third quarter, with the exception of the Millers River at South Royalston (R-4) (Figure 9). Most of the tributary rivers, however, showed a significant rise in average numbers of heterotrophic bacteria from the first to the second quarter, and a comparable drop in numbers in the third quarter. Most Quabbin "inside" and "outside" stations demonstrated a general increase in heterotrophic bacteria populations throughout the three quarters, the major increase in the "outside" stations occurring between the first and second quarters. A general increase in heterotrophic populations was observed in Wachusett Reservoir between the first and second quarters. No overall pattern of increase or decrease, however, was noted in Wachusett Reservoir between the second and third quarters.

Abrupt increases in numbers of total coliform bacteria were noted in almost all systems in the second quarter. Abrupt decreases in these numbers occurred between the second and third quarters (Table 2 and Figure 10).

There was little significant change in numbers of fecal coliform

Table 1. Modal Log Values of Bacterial Numbers per 100 ml for Major Station Groupings, 1971

Modal Log Value	Total Heterotrophic Bacteria			Total Coliform Bacteria			Fecal Coliform Bacteria		
	First Quarter	Second Quarter	Third Quarter	First Quarter	Second Quarter	Third Quarter	First Quarter	Second Quarter	Third Quarter
6.5	MC	MC							
6.0									
5.5			MC						
5.0									
4.5	T	Qi T	Qi T						
4.0									
3.5	Qi	Qo W	Qo W	MC	MC T	MC	MC		
3.0									
2.5	Qo W					T		MC	MC*
2.0									
1.5				T					
1.0									
<1.0				Qi Qo W	Qi Qo W	Qi Qo W	Qi Qo T	Qi Qo W T	Qi Qo W T MC*

*Bimodal distribution

Legend

Qi: Quabbin "inside"
Qo: Quabbin "outside"
W: Wachusett
MC: Millers and Connecticut Rivers
T: Millers Tributaries and Ware River

Table 2. Logarithm of Bacterial Numbers Per 100 ml.

		Heterotrophic Bacteria			Total Coliform Bacteria			Fecal Coliform Bacteria		
Quarter		1	2	3	1	2	3	1	2	3
Quabbin "Outside"	No. of Readings	27	36	18	29	36	20	29	36	20
	Average	3.4	4.0	4.4	<0	0.2	0.3	<0	<0	<0
	Mode	2.5	3.5	3.5	<1	<1	<1	<1	<1	<1
	Range	1.5 4.7	2.7 4.8	3.2 5.4	* 1.0	* 1.3	* 1.0	* 0.3	* 0.0	* 0.7
Quabbin "Inside"	No. of Readings	24	30	16	24	30	16	24	28	16
	Average	4.4	4.3	5.0	0.8	1.2	0.3	0.4	<0	0.2
	Mode	3.5	4.5	4.5	<1	<1	<1	<1	<1	<1
	Range	1.9 5.4	3.0 5.0	3.9 5.9	* 1.9	* 2.0	* 1.0	* 1.7	* 1.0	* 1.0
Wachusett	No. of Readings	19	29	18	21	30	18	21	30	18
	Average	4.1	4.2	3.9	0.1	1.3	0.9	<0	0.6	<0
	Mode	2.5	3.5	3.5	<1	<1	<1	<1	<1	<1
	Range	2.4 5.2	2.8 5.0	3.3 4.4	* 1.0	* 2.4	* 1.7	* 0.6	* 1.5	* 0.6
Millers Tributaries and Ware River	No. of Readings	28	30	21	28	30	21	28	30	21
	Average	4.7	5.2	4.8	3.1	2.9	2.2	0.9	1.7	1.7
	Mode	4.5	4.5	4.5	1.5	3.5	2.5	0.5	<1	<1
	Range	4.0 5.6	4.3 5.9	4.3 5.2	* 2.0	* 3.6	* 2.6	* 1.7	* 2.5	* 2.4

* No Bacteria Detected (hence no log entry for lower limit)

Figure 9. Logarithm of Average Number of Heterotrophic Bacteria per 100 ml

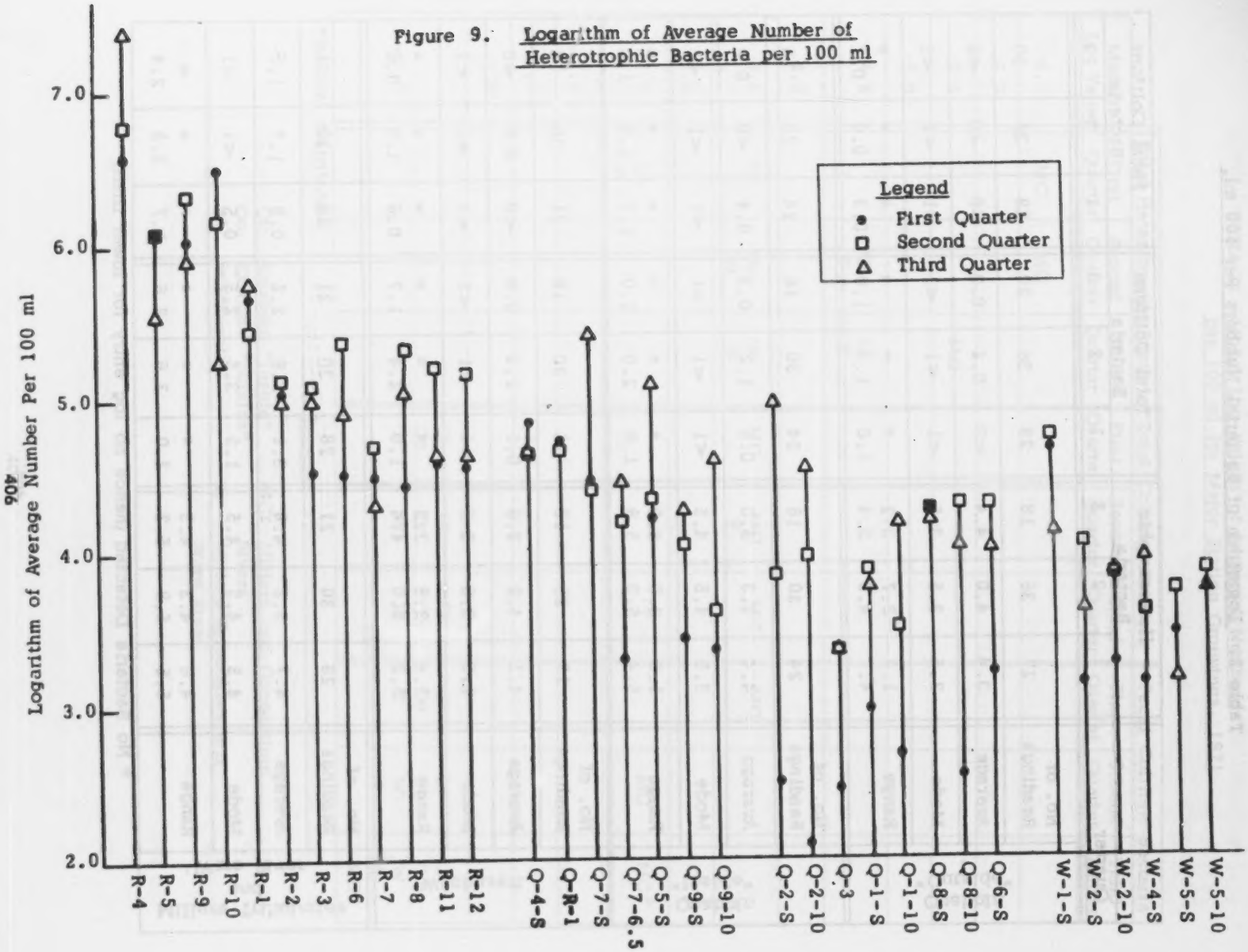
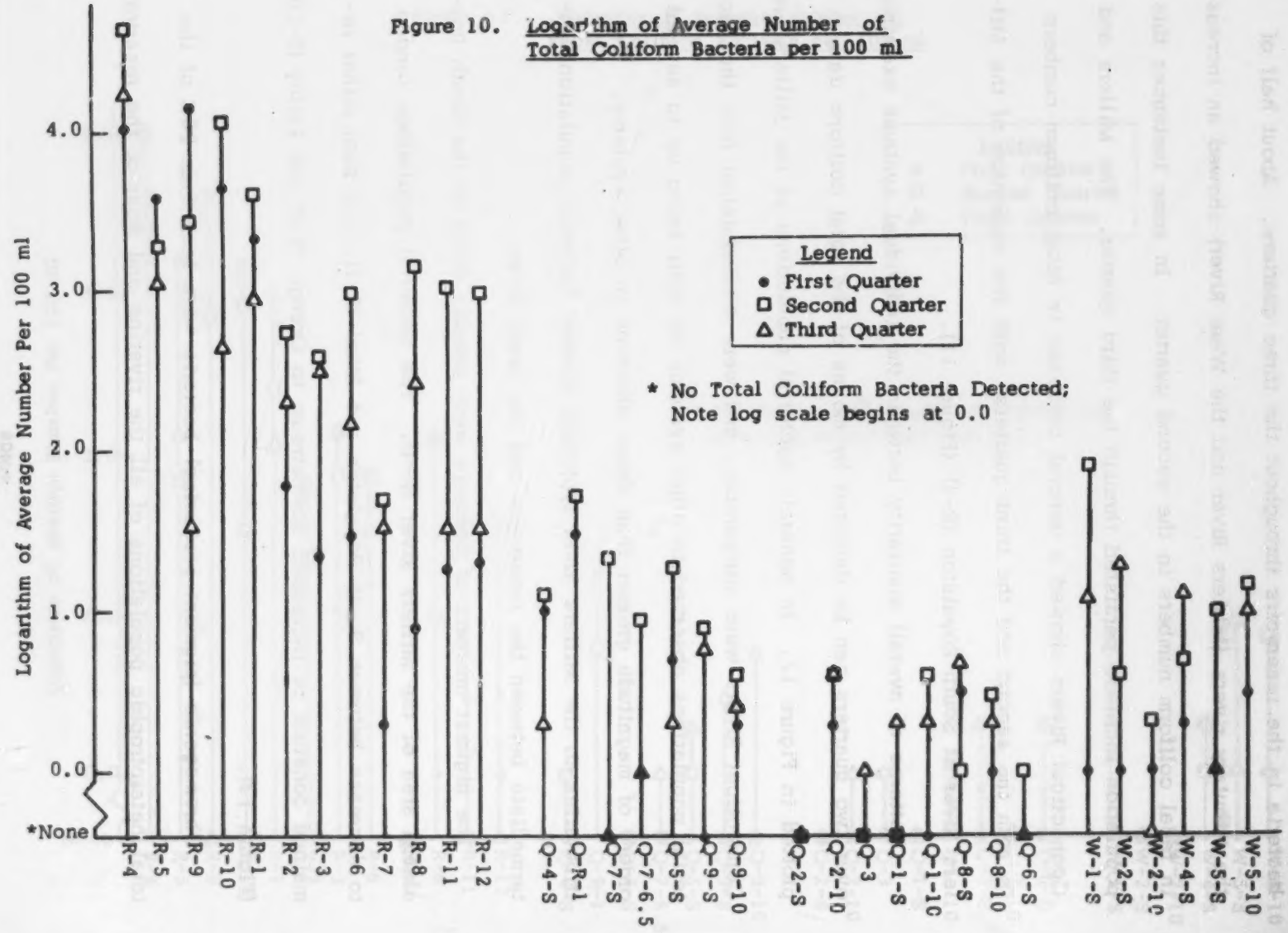


Figure 10. Logarithm of Average Number of Total Coliform Bacteria per 100 ml



bacteria in the reservoirs throughout the three quarters. About half of the tributary rivers (Millers River and the Ware River) showed an increase in fecal coliform numbers in the second quarter. In some instances this population increase persisted through the third quarter. The Millers and Connecticut Rivers showed a general decrease in fecal coliform numbers in both the second and the third quarters, with the exception of the Millers River at South Royalston (R-4) (Figure 11).

Patterns of overall similarity between the individual systems examined over two quarters can be depicted by means of the total coliform data plotted in Figure 12. In general, bacterial populations of the Millers and Connecticut Rivers were comparable, and were distinguished from the bacterial populations observed in other systems by their being up to several orders of magnitude greater than those observed in other systems. The tributaries to the Millers River typically showed bacterial populations intermediate between the reservoirs and the Ware River.

The highest numbers of bacteria were usually found in the South Royalston area of the Millers River (R-4). The bacterial populations tended to decrease between South Royalston and Athol (R-5), and then either remained constant or increased downstream to Orange (R-9) and Farley (R-10) (Figure 13).

Chromogenic (pigment-producing) bacteria were less than 20% of the total heterotrophic populations of all the riverine and most of the reservoir

Figure 11. Logarithm of Average Number of Fecal Coliform Bacteria per 100 ml

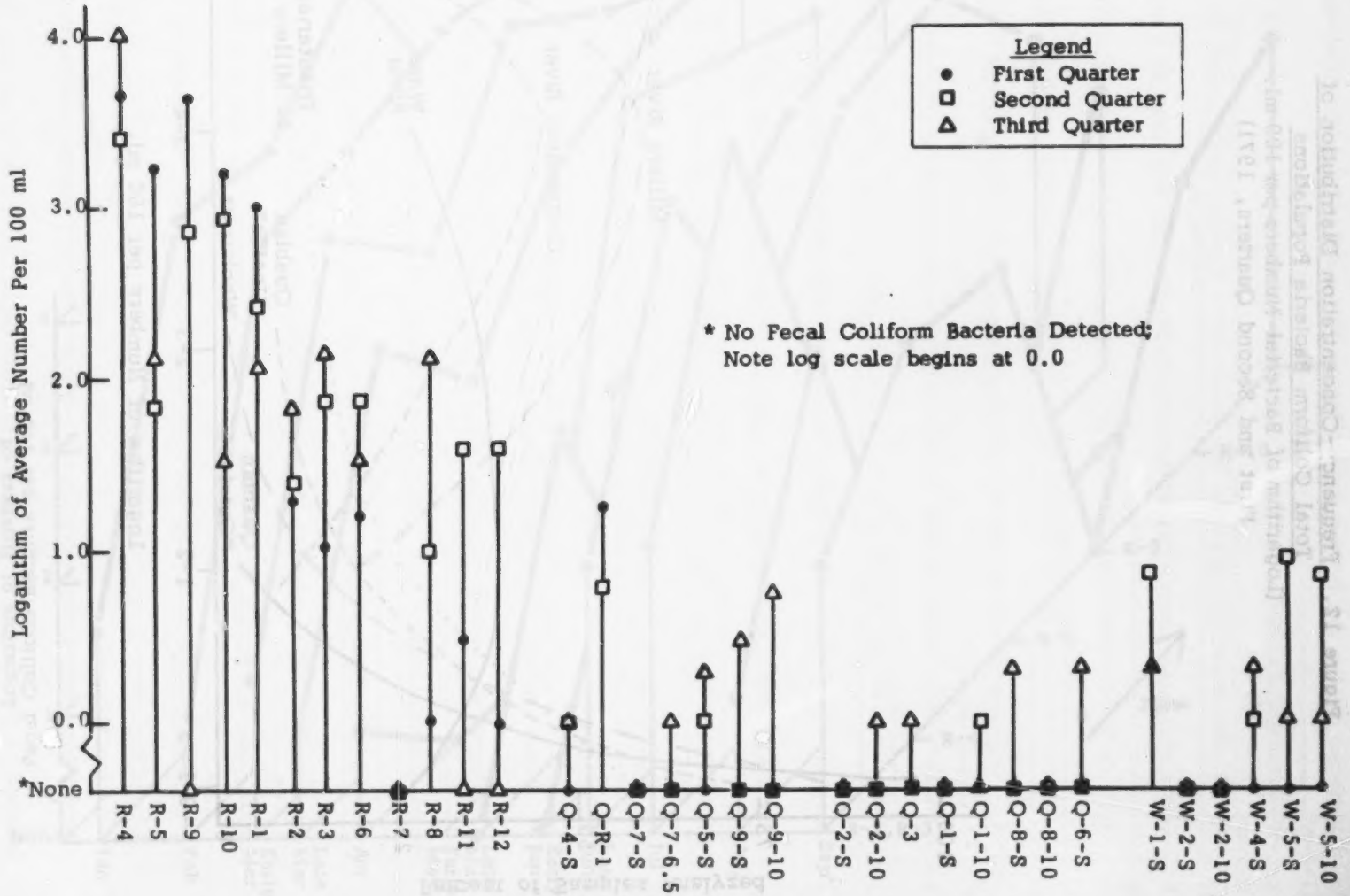
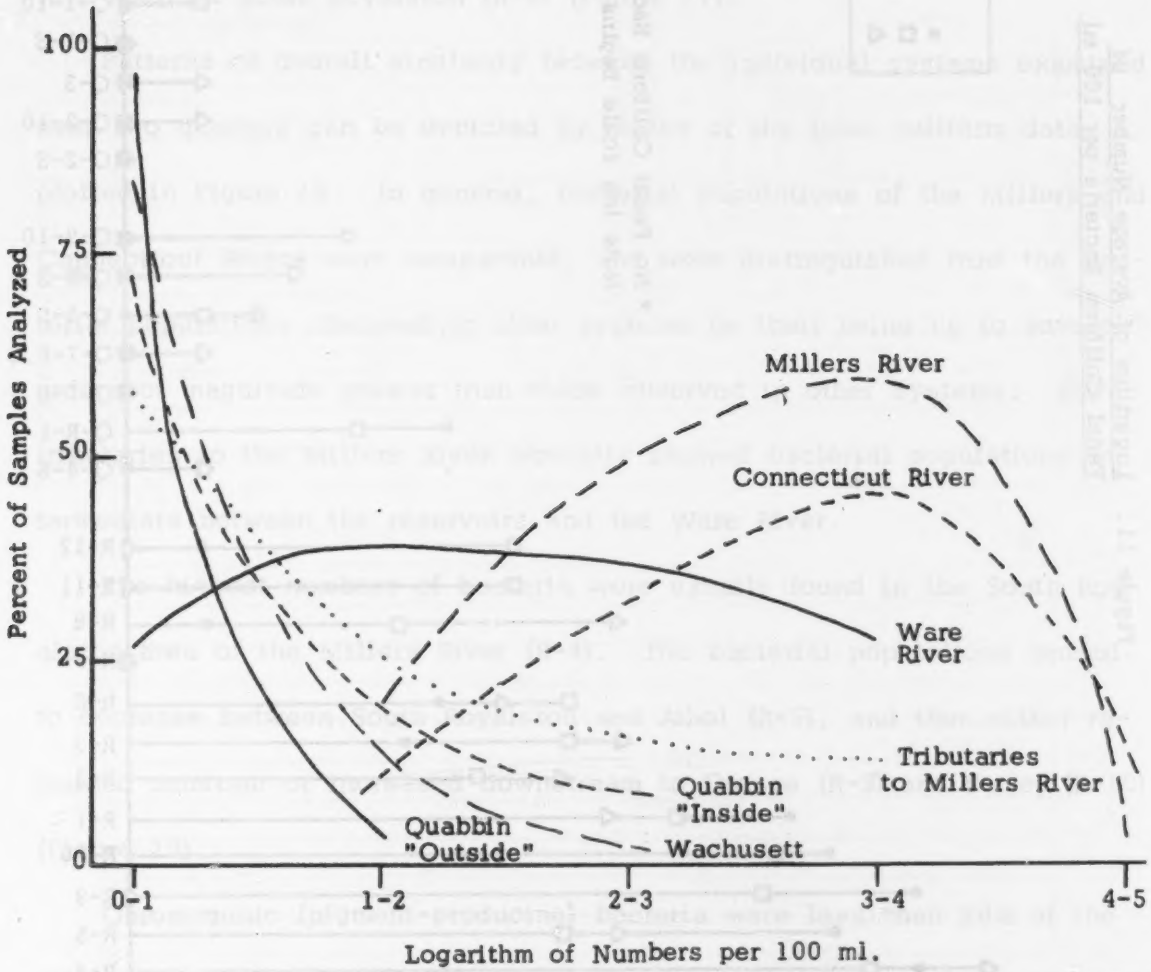


Figure 12. Frequency-Concentration Distribution of Total Coliform Bacteria Populations
(Logarithm of Bacterial Numbers per 100 ml. First and Second Quarters, 1971)



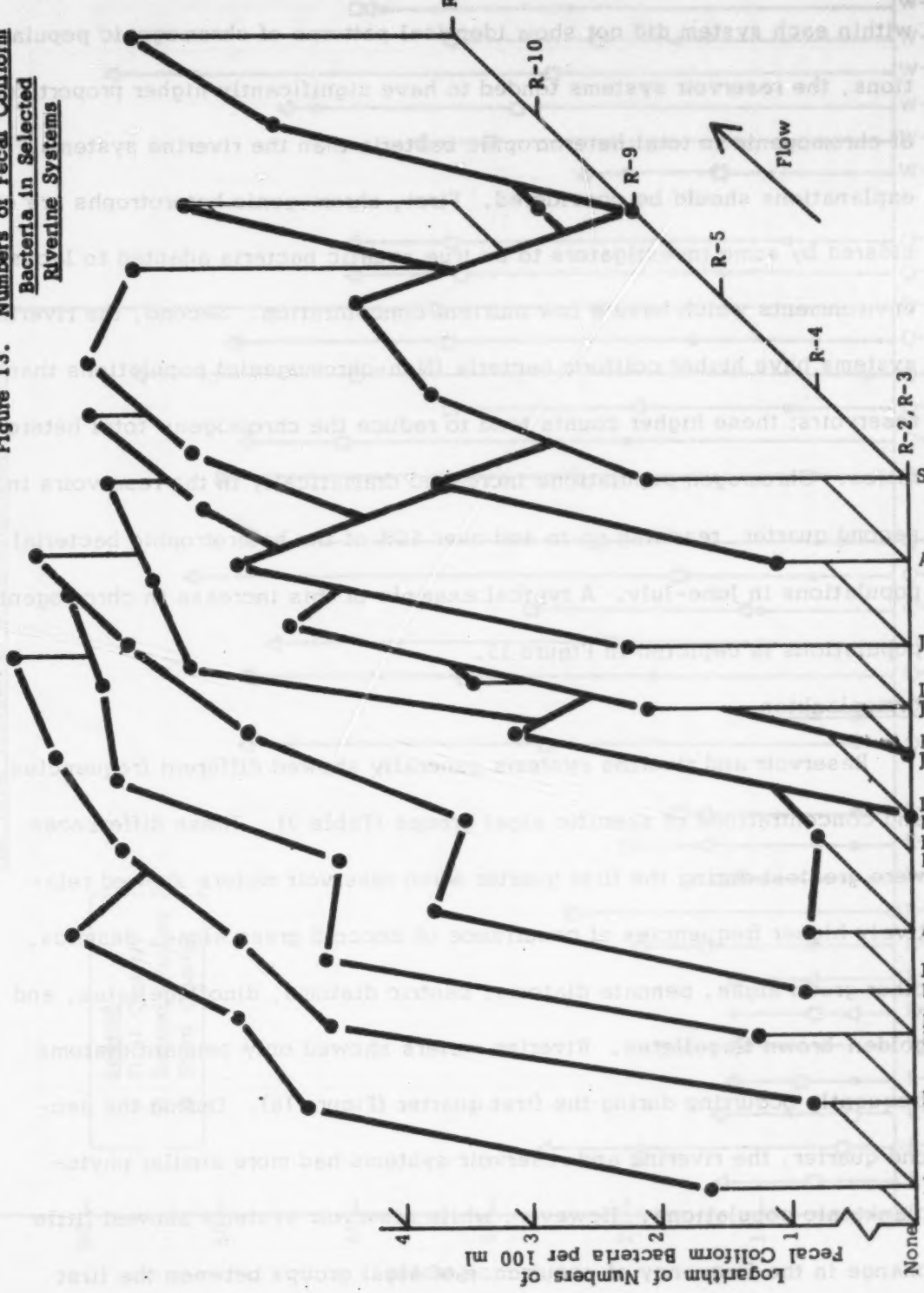


Figure 13. Numbers of Fecal Coliform Bacteria in Selected Riverine Systems

stations during the first quarter (Figure 14). Although individual stations within each system did not show identical patterns of chromogenic populations, the reservoir systems tended to have significantly higher proportions of chromogenic to total heterotrophic bacteria than the riverine systems. Two explanations should be considered. First, chromogenic heterotrophs are considered by some investigators to be true aquatic bacteria adapted to lacustrine environments which have a low nutrient concentration. Second, the riverine systems have higher coliform bacteria (Non-chromogenic) populations than the reservoirs; these higher counts tend to reduce the chromogen: total heterotroph ratios. Chromogen populations increased dramatically in the reservoirs in the second quarter, reaching up to and over 50% of the heterotrophic bacterial populations in June-July. A typical example of this increase in chromogenic populations is depicted in Figure 15.

(2) Phytoplankton

Reservoir and riverine systems generally showed different frequencies and concentrations of specific algal groups (Table 3). These differences were greatest during the first quarter when reservoir waters showed relatively higher frequencies of occurrence of coccoid green algae, desmids, other green algae, pennate diatoms, centric diatoms, dinoflagellates, and golden-brown flagellates. Riverine waters showed only pennate diatoms frequently occurring during the first quarter (Figure 16). During the second quarter, the riverine and reservoir systems had more similar phytoplanktonic populations. However, while reservoir systems showed little change in the frequency of occurrence of algal groups between the first

Figure 14. Chromogenic Bacteria as Average Percent of the Total Population of Heterotrophic Bacteria

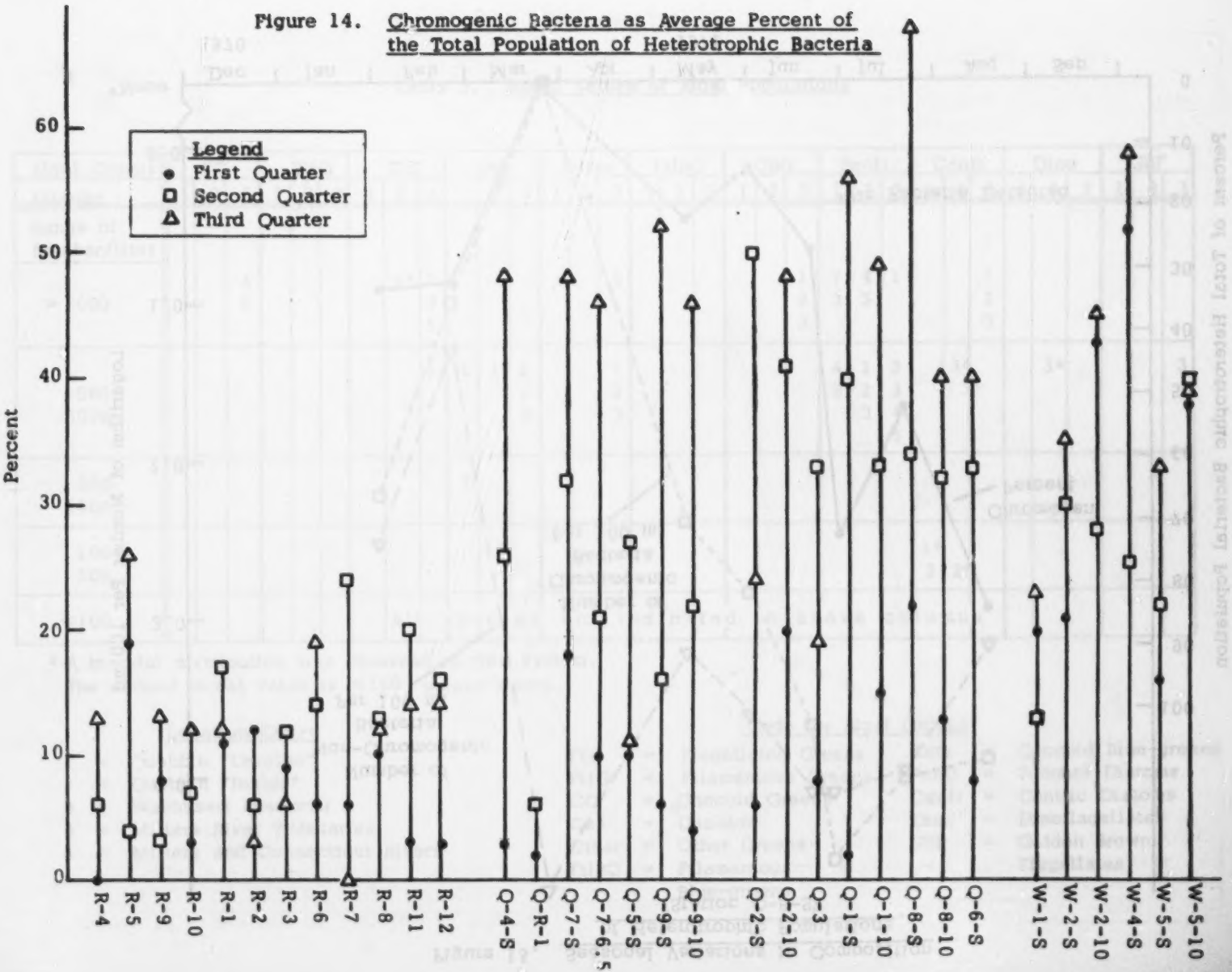


Figure 15. Seasonal Variations in Composition of Heterotrophic Populations (Station Q-8-S)

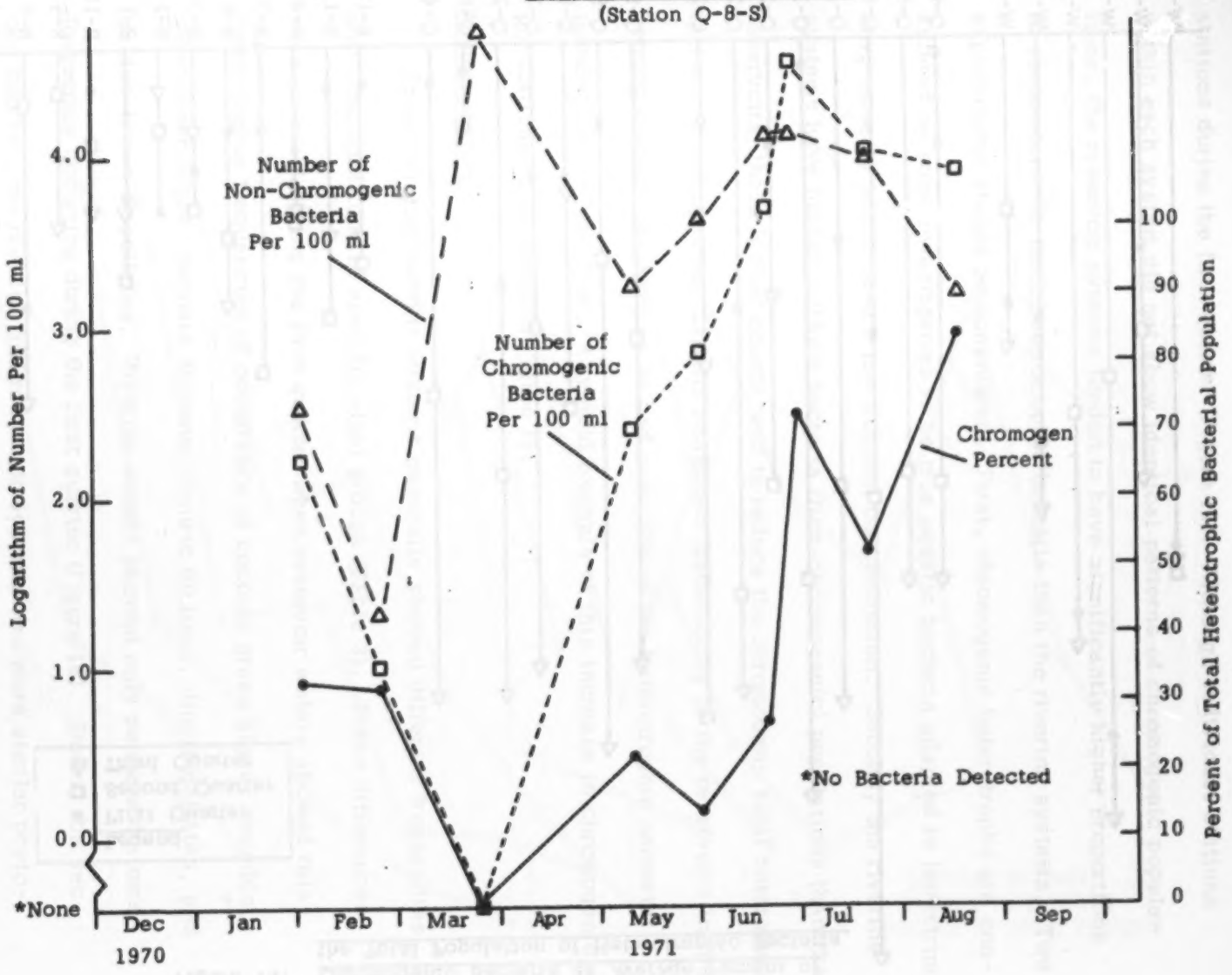


Table 3. Modal Values of Algal Populations

Algal Groups	FG			FilG			CG			Des			Other			FilBG			CBG			PenD			CenD			Dino			GBF		
Quarter	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Range of Number/liter																																	
> 5000			4 5					5*	2 3 5						5						1 2 3	2 3	4 5	1			1 2 3						
1000-5000									1	1	1	1 2 3			1 2 3							4 5	1 2 3	2 3 4 5		3*			3*				3
500-1000										3																							
100-500											3														1* 3	3*							
<100	All systems not indicated in above columns																																

* A bimodal distribution was observed in this system.
The second modal value is <100, unless shown.

Location Codes

1 = Quabbin "Outside"
2 = Quabbin "Inside"
3 = Wachusett Reservoir
4 = Millers River Tributaries
5 = Millers and Connecticut Rivers

Code for Algal Groups

FG = Flagellated Greens
FilG = Filamentous Greens
CG = Coccoid Greens
Des = Desmids
Other = Other Greens
FilBG = Filamentous Blue-greens
CBG = Coccoid Blue-greens
PenD = Pennate Diatoms
CenD = Centric Diatoms
Dino = Dinoflagellates
GBF = Golden Brown Flagellates

Figure 16. Percent of Samples in Which Algal Groups Present (First Quarter, 1971)

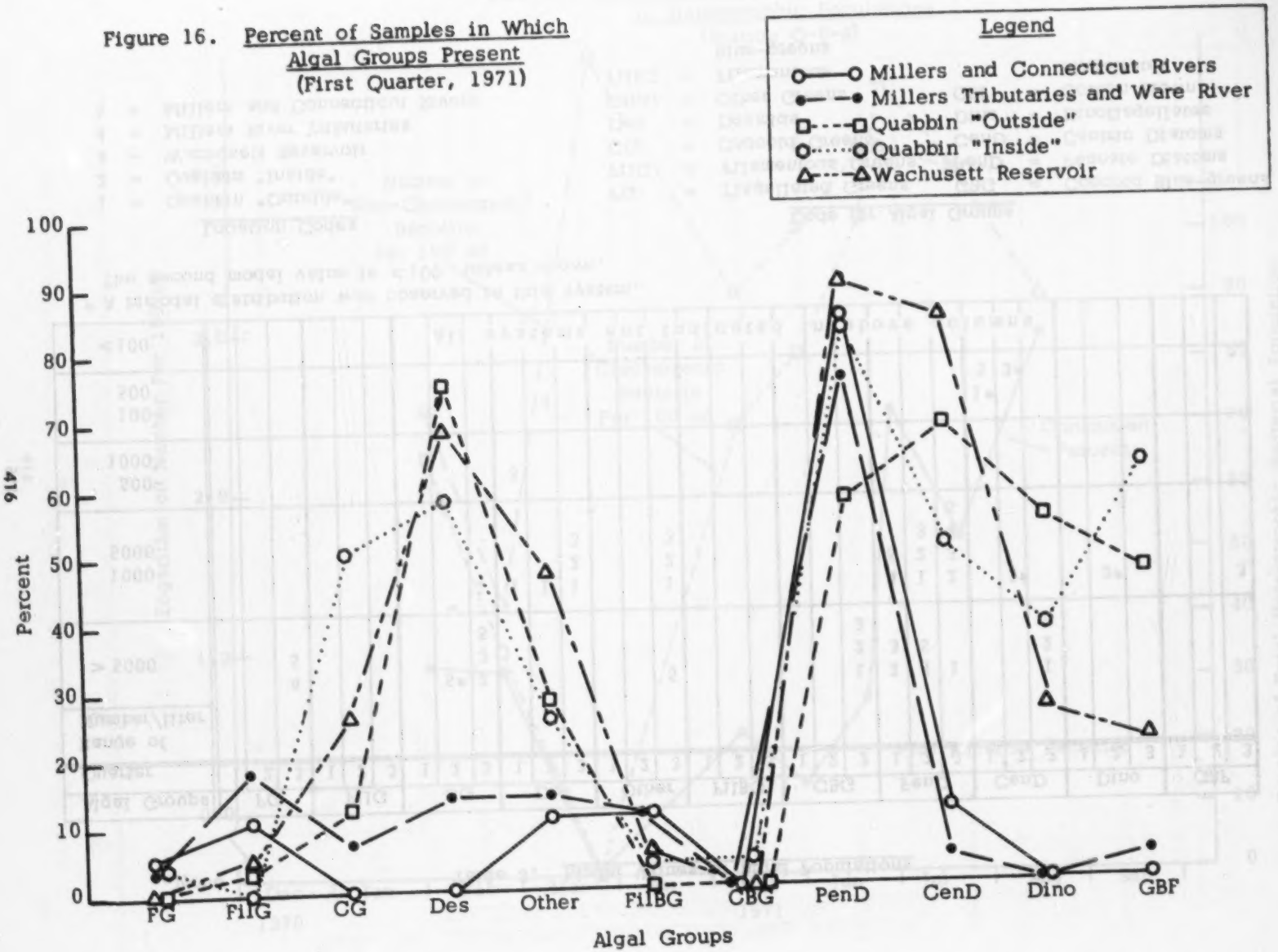
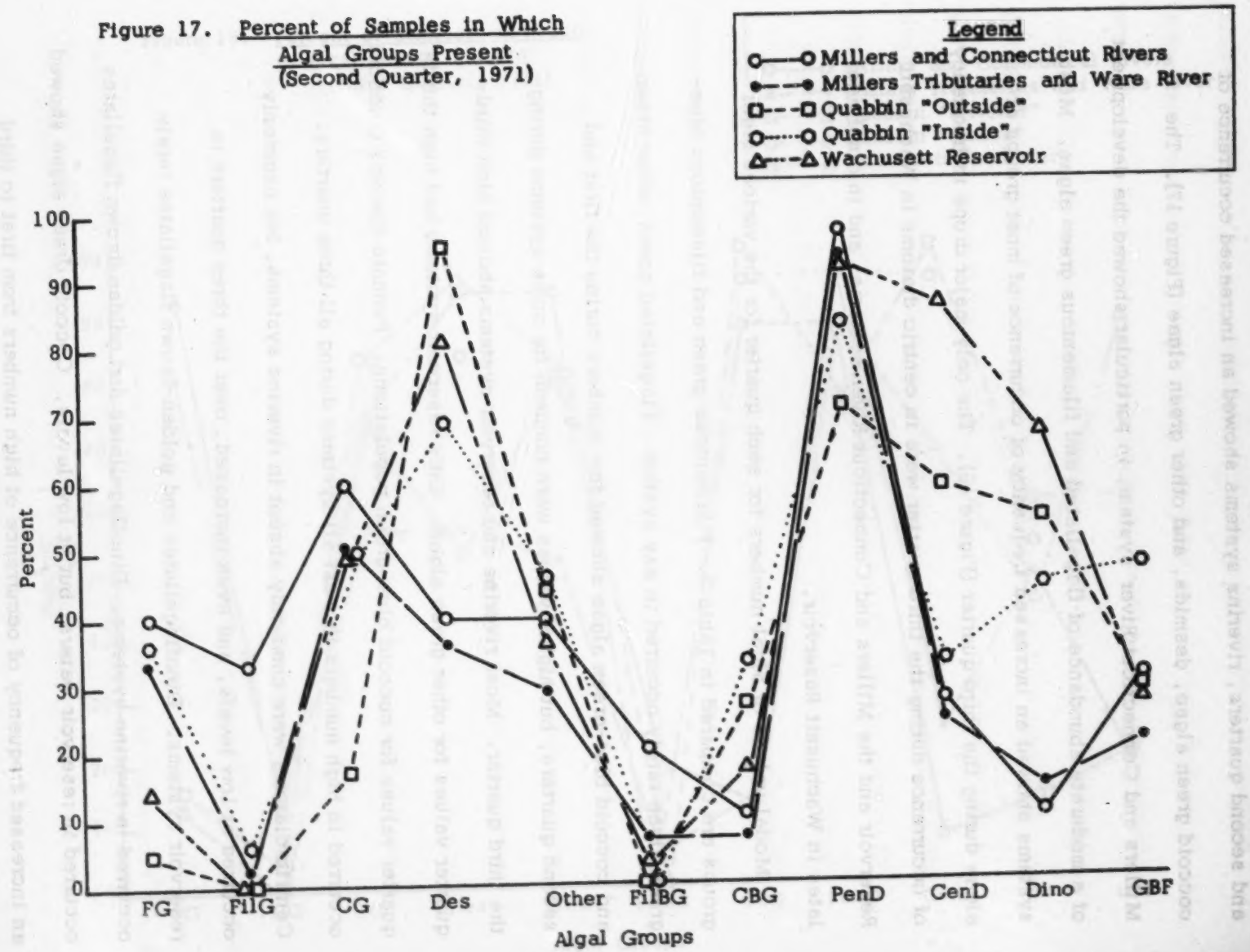


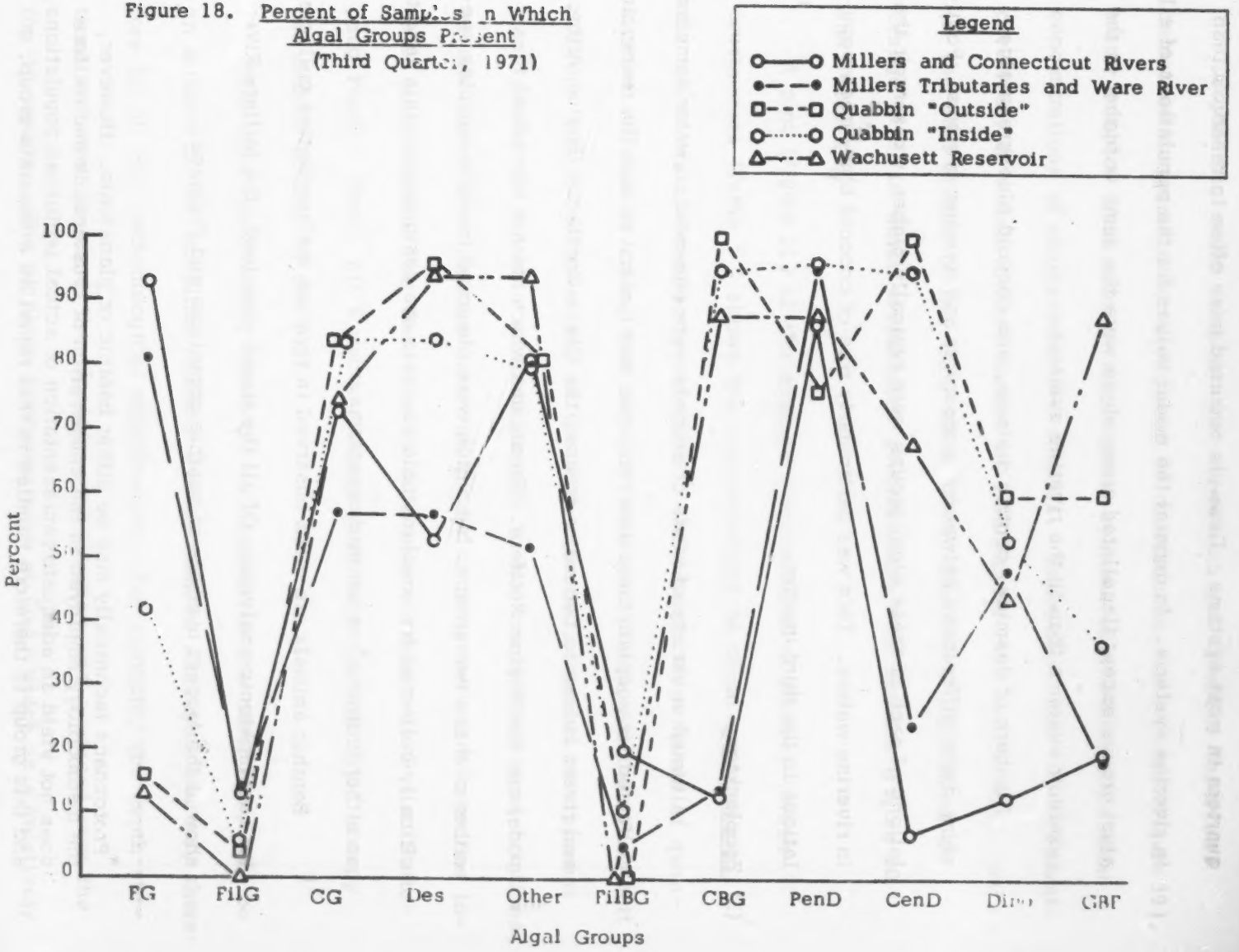
Figure 17. Percent of Samples in Which Algal Groups Present (Second Quarter, 1971)



and second quarters, riverine systems showed an increased occurrence of coccoid green algae, desmids, and other green algae (Figure 17). The Millers and Connecticut River system, in particular showed the development of a moderate abundance of flagellated and filamentous green algae. Most systems showed an increased frequency of occurrence of most groups of algae during the third quarter (Figure 18). The only major drops in frequency of occurrence during the third quarter were in centric diatoms in Wachusett Reservoir and the Millers and Connecticut River systems, and in dinoflagellates in Wachusett Reservoir.

Modal values of algal numbers for each quarter for the various algal groups are compared in Table 3. Filamentous green and filamentous blue-green algae rarely occurred in any system. Flagellated green, other green and coccoid blue-green algae showed few numbers during the first and second quarters, but higher values were common for some systems during the third quarter. Most riverine and reservoir systems showed high third-quarter values for other green algae. Only reservoir systems had high third-quarter values for coccoid blue-green populations. Pennate diatoms commonly occurred in high numbers in most all systems during all three quarters. Centric diatoms were commonly absent in riverine systems, but commonly occurred at low levels, and even increased, over the three quarters in reservoir systems. Dinoflagellates and golden-brown flagellates rarely occurred in riverine systems. Dinoflagellates and golden-brown flagellates occurred in reservoir waters, but at low levels. Coccoid green algae showed an increased frequency of occurrence of high numbers from first to third

Figure 18. Percent of Samples in Which Algal Groups Present
(Third Quarter, 1971)



quarters in most systems. Desmids occurred more often in reservoir than in riverine systems. In general the modal values for the populations of all algal groups except flagellated green algae were the same or higher in the reservoir systems than in the riverine systems.

Numbers of desmids, centric diatoms, and coccoid blue-green algae show major differences between the reservoir and riverine systems. Populations of each of these algal groups were typically higher in reservoir than in riverine waters. This was particularly true of coccoid blue-green populations in the third quarter.

(3) Zooplankton

Although a variety of kinds of animals were observed in water samples collected for zooplanktonic analysis, the zooplankton of both the reservoirs and rivers belong to two major groups, the Class Crustacea (Phylum Arthropoda) and the Phylum Rotifera. Organisms which are not classified in either of these two groups, but which were observed in water samples specifically collected for zooplanktonic analysis are designated in this report as either Protozoa* or benthic organisms.

Benthic animals are often observed in riverine surface waters collected for zooplanktonic analysis. Of all the rivers examined, the Millers River showed the largest numbers of benthic organisms and Protozoa.

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*Protozoans technically may be either benthic or planktonic. However, the methodology employed in the enumeration of crustaceans and rotifers does not yield an adequate representation of actual protozoan populations, and this group is therefore handled in this report as a separate group.

In general, water samples from Wachusett and Quabbin Reservoirs contained comparable concentrations of crustaceans and rotifers (Figure 19). Water samples from most of the riverine systems also contained similar concentrations of crustaceans and rotifers. Exceptions were (1) Connecticut River, in which rotifers tended to predominate over crustaceans, and (2) the East Branch of the Tully River (R-7), and the Millers River at Orange (R-9) in which crustaceans predominated over rotifers (Figure 20 and Table 4).

A plot (Figure 21) of the average concentration of rotifers versus crustaceans (Table 5) shows the concentrations of these organisms in the reservoirs to be directly correlated, and reveals three kinds of quantitative differences among the reservoir stations. First, all the Wachusett stations are at the lower end of the plot. Second, there is an apparent trend among the Quabbin stations of high to low zooplankton concentrations as one moves from stations near the inputs to the reservoir to stations located near outputs from the reservoir (the only exception is Q-4 at Pottapaug Pond). Third, all 6 depth stations (see note on Figure 21) occupy the middle portion of the plot.

This third observation, however, in contrast to the other two, may be an artifact of the sampling patterns and procedures employed and may therefore be of only methodological significance. For example, the depth stations are ones in which the plankton concentration was averaged over the top 10 meters. The plankton concentrations at Q-5, which is a relatively

Figure 19. Monthly Variations in Numbers of Reservoir Zooplankton

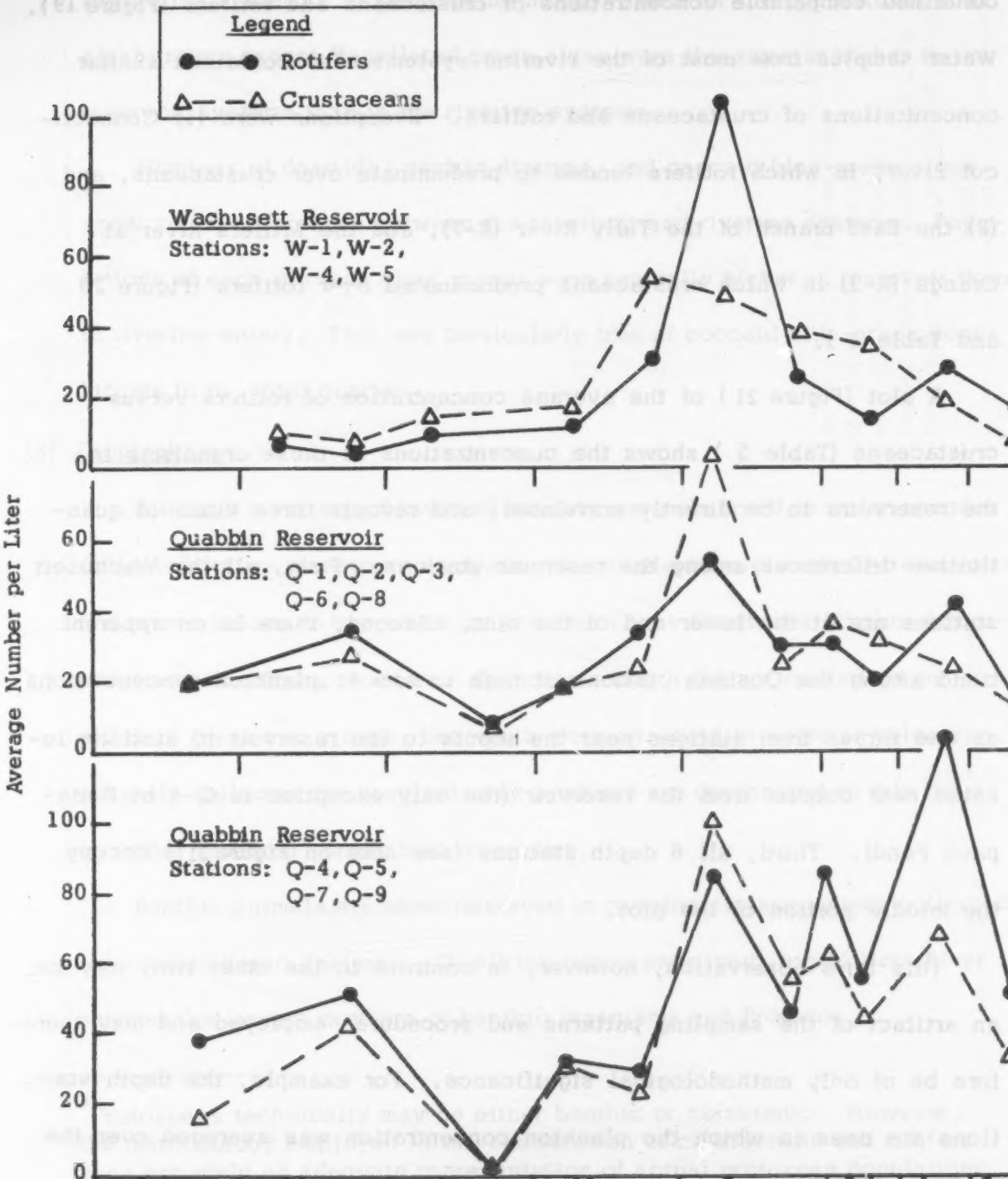

Figure 20. Monthly Variations in Numbers of Riverine Zooplankton

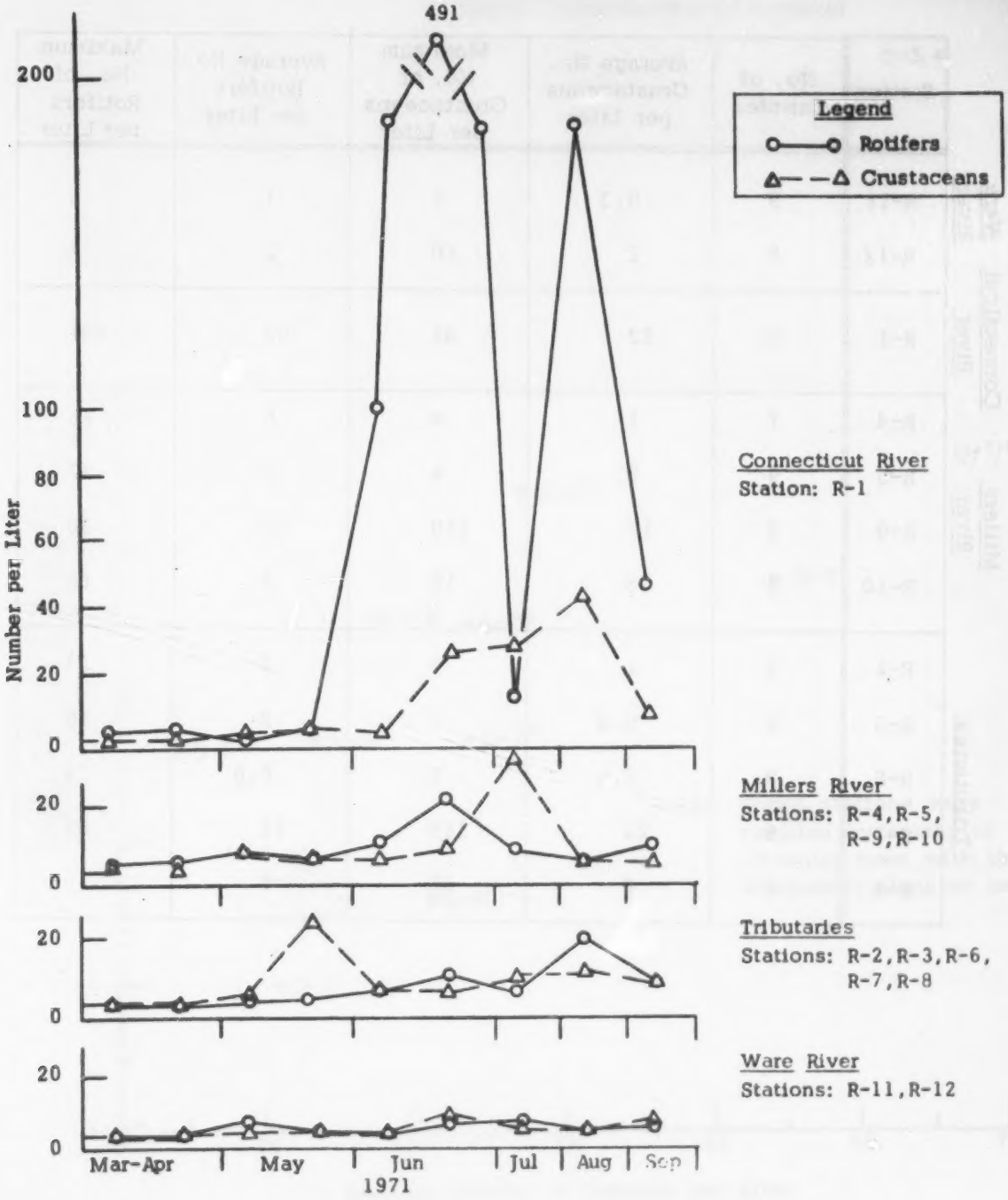

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Table 4. Riverine Zooplankton
(March through September, 1971)

	Station	No. of Samples	Average No. Crustaceans per Liter	Maximum No. of Crustaceans per Liter	Average No. Rotifers per Liter	Maximum No. of Rotifers per Liter
Ware River	R-11	9	0.3	1	1	6
	R-12	9	2	10	2	7
Connecticut River	R-1	9	12	41	93	491
Millers River	R-4	7	1	4	6	26
	R-5	9	2	6	5	27
	R-9	9	17	119	10	30
	R-10	9	3	10	4	15
Tributaries	R-2	9	1	3	2	13
	R-3	9	0.4	1	2	16
	R-6	9	0.6	5	0.6	3
	R-7	9	23	116	15	89
	R-8	9	4	18	1	8

Figure 21. Reservoir Zooplankton

(concentration of crustaceans versus concentration of rotifers)

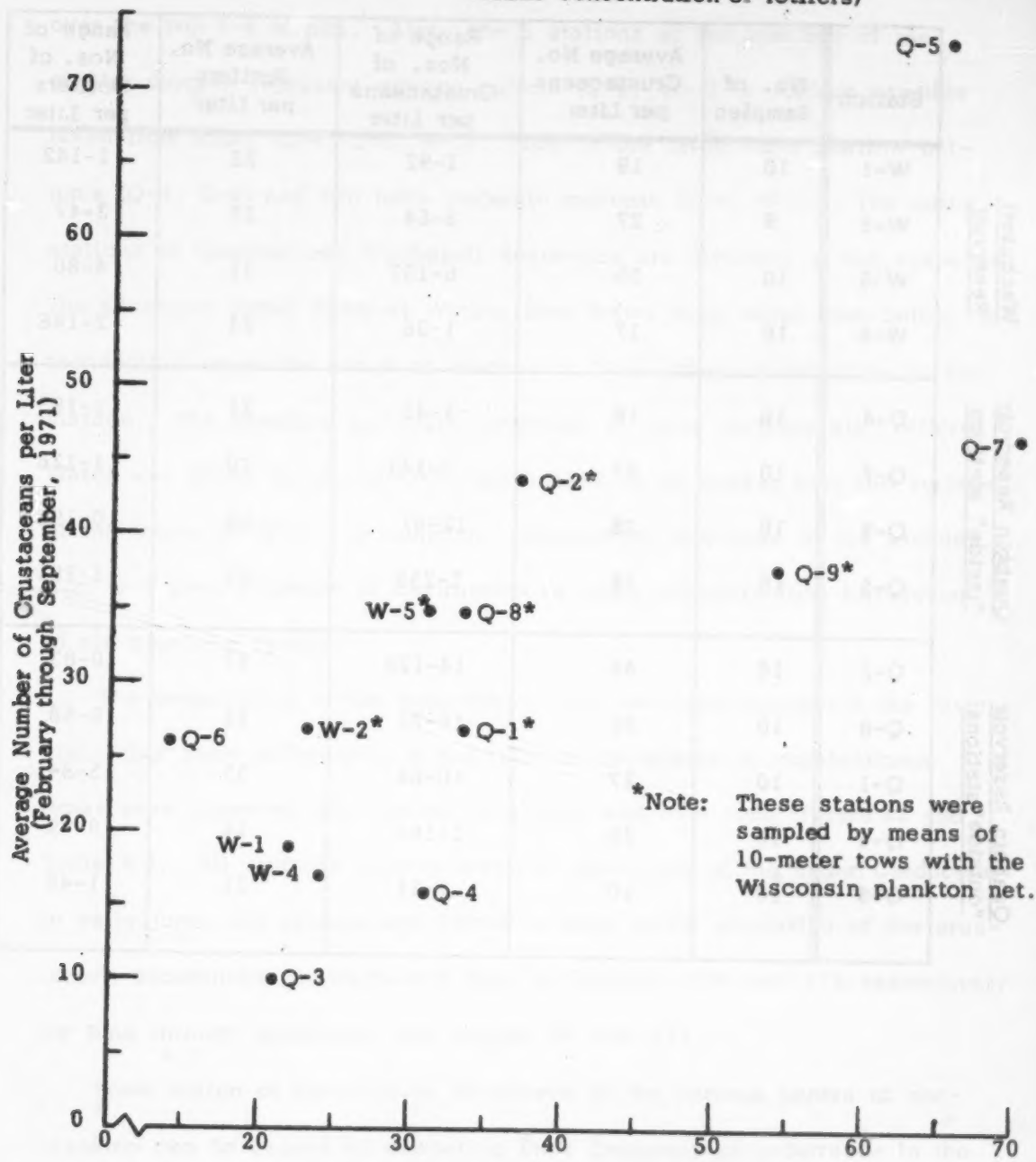


Table 5. Reservoir Zooplankton
(February through September, 1971)

	Station	No. of Samples	Average No. Crustaceans per Liter	Range of Nos. of Crustaceans per Liter	Average No. Rotifers per Liter	Range of Nos. of Rotifers per Liter
Wachusett Reservoir	W-1	10	19	1-92	22	1-142
	W-2	9	27	3-64	23	3-47
	W-5	10	35	6-137	31	4-80
	W-4	10	17	1-36	24	2-146
Quabbin Reservoir "inside" stations	Q-4	10	16	1-45	31	1-183
	Q-7	10	47	7-143	70	1-126
	Q-9	10	38	12-61	54	10-192
	Q-5	10	74	1-259	65	1-281
Quabbin Reservoir "outside" stations	Q-2	10	44	14-129	37	10-83
	Q-8	10	35	16-71	33	8-58
	Q-1	10	27	10-64	33	15-84
	Q-6	10	26	1-160	14	0-49
	Q-3	10	10	1-21	21	1-48

shallow station, were averaged over the top 1 meter. Because of similar considerations of depth, the plankton concentrations at Q-7 were averaged over the top 5-6 meters. Also, the 5 stations at the low end of the scatter diagram represent running outlets (Q-3, W-4) or surface samples taken from shore (Q-4, Q-6, W-1). Two of the latter have shallow bottoms (Q-4, Q-6) and two have moderate currents (Q-4, W-1). The outlet stations in Quabbin and Wachusett Reservoirs are different in two respects. The Chicopee outlet (Q-3) at Winsor Dam draws deep water from below the thermocline while the outlet at Wachusett (W-4) draws water close to the surface. The sampling technique employed at these stations also differed. Water was drawn by tap at Q-3, but hauled up by bucket from the surface of the intake at W-4. In addition, zooplankton fragments in the samples from Q-3 gave evidence of destruction of some plankters from turbulence in the plumbing system.

The composition of the zooplankton was the same throughout the reservoirs, but some differences in the relative abundance of zooplanktonic types were observed from station to station and over time (Figure 22 and Table 6). All stations show a dramatic expansion of the Order Cladocera in early June, but cladocerans formed a much larger proportion of the crustacean zooplankton in Wachusett than in Quabbin (57% and 37% respectively for June through September; see Figures 22 and 23).

Some notion of the relative abundance of the various genera of zooplankton can be gained by comparing their frequency of occurrence in the

Figure 22. Seasonal Variations in Composition of Reservoir Zooplankton

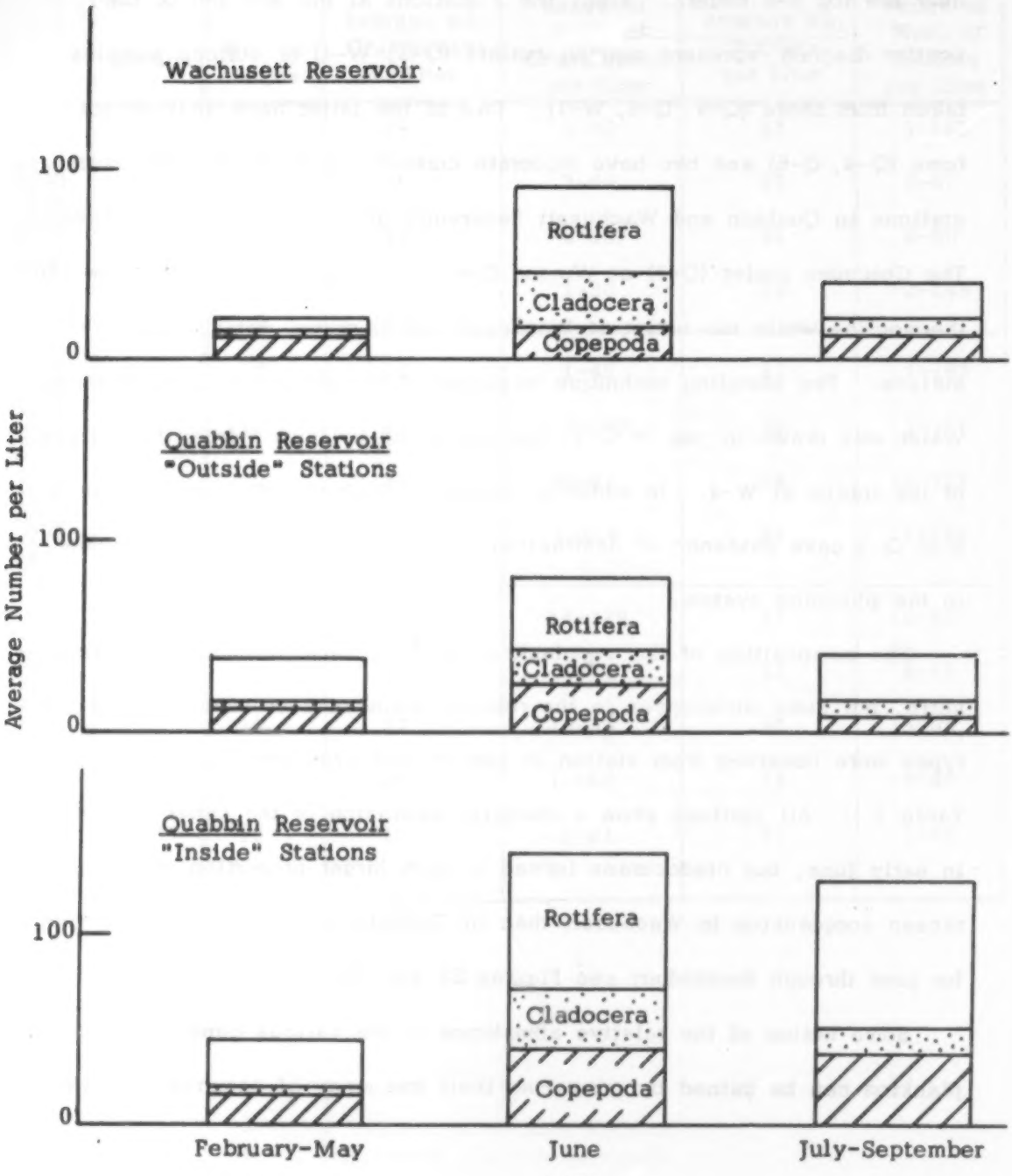
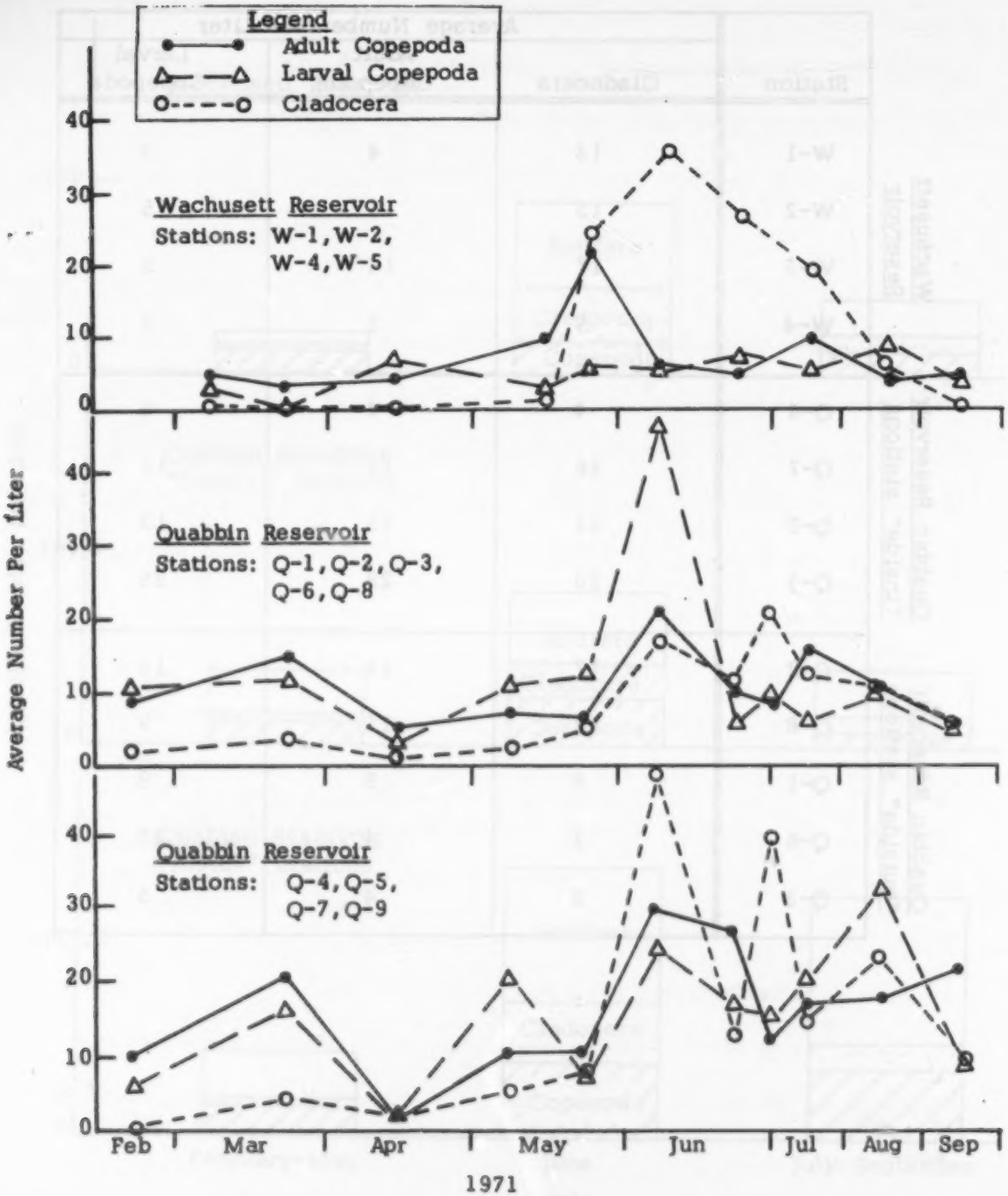


Table 6. Reservoir Crustaceans
(February through September, 1971)

	Station	Average Number Per Liter		
		Cladocera	Adult Copepoda	Larval Copepoda
Wachusett Reservoir	W-1	13	4	3
	W-2	15	6	5
	W-5	17	14	5
	W-4	5	5	7
Quabbin Reservoir "inside" stations	Q-4	4	4	8
	Q-7	26	11	11
	Q-9	11	15	13
	Q-5	20	28	25
Quabbin Reservoir "outside" stations	Q-2	17	14	13
	Q-8	12	15	9
	Q-1	8	9	9
	Q-6	2	4	20
	Q-3	2	4	5

Figure 23. Monthly Variations in Numbers of Reservoir Zooplankton



samples (Table 7). The only genus which can be readily used to differentiate groups of reservoir stations from each other was the colonial rotifer Conochilus. Conochilus was present in 69% of the Quabbin "inside" station samples, and 58% and 53% of the Quabbin "outside" and Wachusett stations,respectively. Conochilus was not only present but was also noted as the predominant rotifer in 43% of the Quabbin "inside" station samples, but in only 17% of the samples from all other reservoir stations. Conochilus did not make its appearance in the reservoirs until May, and its predominance within the rotifer population was associated with all but one of the subsequent rotifer peaks shown in Figure 19. In Wachusett Reservoir Conochilus was predominant in 7 of the 8 samples taken in the June and August peak periods, and was not predominant in any of the 16 samples taken during non-peak periods. In Quabbin Reservoir Conochilus was predominant in 12 of the 22 samples taken in the peak periods, and in only 7 of the 30 samples taken during non-peak periods.

Rotifers and crustaceans which were commonly found in the reservoirs were also found in the rivers (Table 7), but there was a greater variety of rotifers in the rivers than in the reservoirs. Many riverine rotifers lacked the skeletons characteristic of reservoir rotifers, and were observed to be actively climbing on debris.

The frequencies of occurrence of riverine zooplankton were less than those of reservoir zooplankton, and the average concentration of zooplankton at most of the riverine stations was about one order of magnitude less

Table 7. Relative Composition of Reservoir and Riverine Zooplankton Samples

Note from the numbers of samples in the reservoirs (column 3) that subcategories of Rotifera, Copepoda and Cladocera were not identified for all samples.

Type of Organism	% of Reservoir Samples in which present	Total Reservoir Samples	% of Riverine Samples in which present	Total Riverine Samples
ROTIFERA	99	129	67	106
Keratella	84	116	33	106
Kellicottia	80	116	8	106
Polyarthra	75	116	13	106
Conochilus	59	116	14	106
Gastropus	26	116	12	106
Lepadella	5	116	2	106
Monostyla	4	116	5	106
Asplanchna	3	116	0	106
Filinia	3	116	1	106
Unidentified	52	116	46	106
CRUSTACEA	100	129	63	106
Copepoda	100	129	52	106
Calanoid	82	109	5	106
Cyclopoid	83	109	19	106
Harpacticoid	2	109	0	106
Larvae	98	129	42	106
Ostracoda	0	129	5	106
Cladocera	87	129	34	106
Bosmina	73	113	25	106
Holopedium	67	113	4	106
Daphnia	60	113	7	106
Polyphemus	7	113	3	106
Leptodora	5	113	0	106
Scapholeberis	0	113	5	106
Chydoridae	4	113	5	106
PROTOZOA	9	129	32	106
BENTHICS	19	129	51	106
Turbellaria	7	129	7	106
Chironomidae	4	129	33	106
Acari	3	129	9	106
Oligochaeta	3	129	11	106
Nematoda	2	129	17	106
Miscellany	5	129	7	106

than that of reservoir stations (Tables 4, 5 and Figure 24). Exceptions were those concentrations observed at R-1 (Connecticut River), R-7 (East Branch of Tully River), and R-9 (Millers River at Orange).

Zooplankton populations did not develop in rivers until late May or June (Figure 20). Rotifer concentrations peaked in most rivers in late June, with the exception of Tarbell Brook (R-2) and possibly the Ware River (R-11, R-12) where concentrations remained too low to show a discernible pattern. The high June peak in rotifer concentration in the Connecticut River (Figure 20) was associated with 8 genera. No one type was predominant. However, in August only two rotifers were present in the Connecticut River, Polyarthra and Keratella.

In general, the riverine stations examined fall into 3 basic groups with respect to overall plankton concentrations:

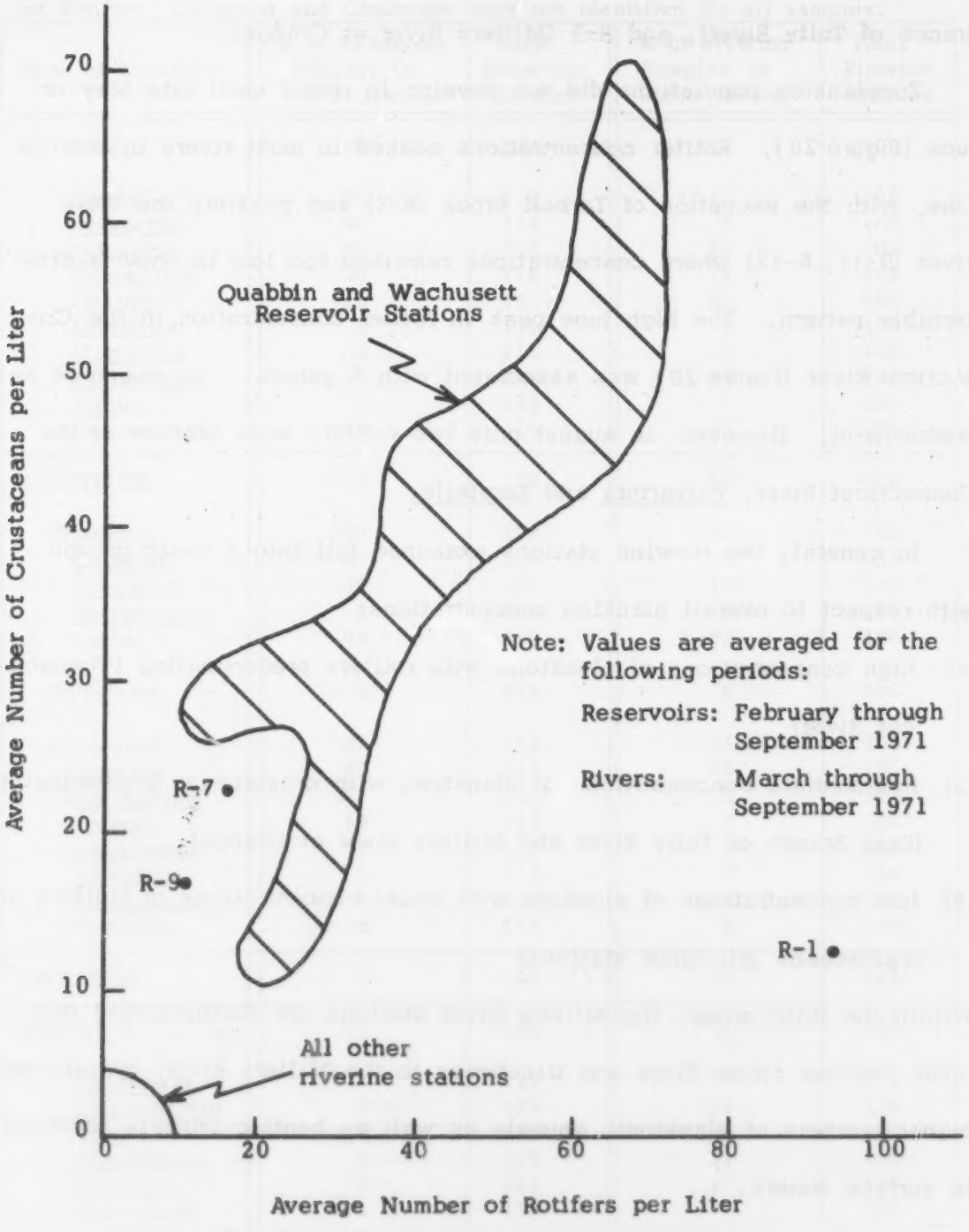
(a) high concentrations of plankton, with rotifers predominating (Connecticut River)

(b) intermediate concentrations of plankton, with crustaceans predominating (East Branch of Tully River and Millers River at Orange)

(c) low concentrations of plankton with equal concentrations of rotifers and crustaceans (all other stations)

Within the third group, the Millers River stations are distinguished from all other stations (Ware River and tributaries to the Millers River) by relatively higher numbers of planktonic animals as well as benthic animals observed in surface waters.

Figure 24. Riverine and Reservoir Zooplankton (concentrations of crustaceans versus concentrations of rotifers)



(4) Benthic Organisms

At the beginning of the project, benthic samples were collected monthly at each station. Beginning in May, benthic organisms were collected along transects in the reservoirs, and by multiple samples in the rivers on a quarterly schedule. Basic differences between the transects made in reservoirs are summarized in Table 8. These differences in depth, plant communities, and nature of bottom muds are associated with differences in the kinds of populations and distributions of benthic organisms observed in these aquatic systems. Two major types of distributions were detected (Table 9). One type included animals generally distributed in muds throughout the reservoirs. These animals were present in higher concentrations in Wachusett Reservoir. A second type included animals largely restricted to littoral areas, or associated with the presence of aquatic plants. These animals were present in higher concentrations along the Q-5 transect in Quabbin Reservoir.

Localized concentrations of individual groups of benthic organisms, however, were not observed to be directly correlated with their general type of distribution. The Pelecypoda, for example, were present in higher concentrations along the Q-5 transect than at any other transect, even though they were generally distributed throughout the reservoir.

The highest average concentration of Chironomidae (from February through September inclusive) was observed in the northeast area of Wachusett Reservoir (W-5), and the lowest in the area of Shaft 12 in Quabbin

Table 8. Comparison of Various Conditions Associated With Bottom Samples of Reservoirs

Station in Immediate Area of Transect	Average Depth of Sampling Points on Transect	Plants Present	Nature of Bottom Mud
W-2	19 meters	No	Very fine mud composed of well decomposed organic material
W-5	19 meters	No	
Q-1	18 meters	Yes (in 6 of 20 samples)	Generally large amounts of only partly decomposed organic material (leaves, twigs, bark, etc.). Least amount of such debris consistently noted in area of station Q-2
Q-2	16 meters	Yes (in 2 of 16 samples)	
Q-5	3 meters	Yes (in all 17 samples)	
Q-7	11 meters	No	
Q-8*	11 meters	No	
Q-9*	13 meters		

*Note: These stations were sampled individually in the first quarter, and were not included as points on a transect in subsequent sampling periods.

Table 9. General Distributions of Benthic Organisms in Quabbin and Wachusett Reservoirs

Type of Distribution	Animals Present	Percent of Samples in Which Found	Average No. per Grab Sample *
I. Animals generally distributed among all stations	Chironomidae	98	17.1
	Oligochaeta	77	5.8
	Pelecypoda	42	1.7
	Isopoda	30	0.9
	Acari	35	0.8
	Turbellaria	23	0.8
II. Animals associated with weeds and/or littoral areas of reservoirs	Amphipoda	27	2.3
	Gastropoda	15	1.1
	Heleidae	16	0.4
	Cladocera & Copepoda	9	0.3
	Odonata, Ephemeroptera, and Trichoptera Larvae	16	0.2

* 1/4 ft^2

Reservoir (Q-1) (Table 10). The highest average concentration of Oligochaeta was also observed along the W-5 transect, and the lowest in the western arm of Quabbin Reservoir (Q-2).

There were seasonal differences in the average concentration of organisms (Table 11). Minimum values occurred at different seasons for different animals.

Chironomids were most often found in highest concentrations during the earliest sampling period, before the emergence of the adult flies. After an overall decrease in concentrations in May and June, chironomid concentrations again began to increase in late summer. However, individual transects demonstrated variation to this general pattern (Table 12). Transects in the area of W-2, W-5, and Q-1 all showed a sharp rise in chironomid populations between July and September, whereas transects in the area of Q-2, Q-5, and Q-7 showed decreases. These changes in concentrations at individual transects were associated with changes in genera of chironomids. For example, September increases in chironomid concentrations at the W-2 and W-5 transects reflected increases in numbers of Calopsectra.

Peculiarities of individual transects were also noted in seasonal variations of Oligochaeta concentrations (Table 12). Oligochaetes showed drops in concentrations between July and September except at the Q-5 transect which showed a significant increase. The smallest seasonal variation in numbers of oligochaetes was observed at the Q-2 transect, and

Table 10. Concentrations of Chironomidae and Oligochaeta in Quabbin and Wachusett Reservoirs

Transect Location	Chironomidae			Oligochaeta		
	No. of Samples Processed	Total No. of Organisms Observed	Average No. per Sample*	No. of Samples Processed	Total No. of Organisms Observed	Average No. per Sample*
W-2	14	266	19	14	65	5
W-5	17	380	22	17	167	10
Q-1	20	258	13	20	169	9
Q-2	16	255	16	16	38	2
Q-5	17	267	16	17	70	4
Q-7	16	216	14	16	88	5

* 1/4 ft^2

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Table 11. Seasonal Variations of Benthic Populations in Quabbin and Wachusett Reservoirs
(Average number of animals per grab--1/4 ft^2)

Animals	February, March, April 14 Samples	May, June 30 Samples	July 30 Samples	Septembe 30 Sampl
Chironomidae	36	12	14	16
Oligochaeta	7	8	6	3
Pelycepoda	1	<1	3	2
Isopoda	3	<1	<1	<1
Turbellaria	<1	2	<1	<1
Amphipoda	4	1	2	4

Table 12. Seasonal Variations in Numbers of Oligochaeta and Chironomidae
(Average number of animals per grab - 1/4 ft^2)

	Transect Locations						
	W-2	W-5	Q-1	Q-2	Q-5	Q-7	Q-8 Q-9
Chironomidae							
February, March, April	31	56	13	42	52	20	35
May, June	9	11	14	17	19	8	-
July	9	14	10	21	10	18	-
September	34	28	18	5	4	13	-
Oligochaeta							
February, March, April	3	24	6	4	6	0	3
May, June	8	8	19	2	5	8	-
July	6	14	7	2	<1	8	-
September	1	3	3	2	6	1	-

the largest, at W-5.

The river systems show differences in both the kinds and numbers of animals present. Three of the Millers River stations had the fewest kinds of animals present but the highest numbers of animals per square foot, frequently over a thousand per square foot (Table 13 and Figure 25). This lack of correlation between numbers and diversity in the Millers River is illustrated in Figure 26 for samples from two types of river bottoms. All but one of the muddy bottom samples came from stations R-4 (South Royalston), R-5 (Athol) and R-9 (Orange), whereas most of the samples from sandy or gravel bottoms came from R-10 (Farley). At R-10 there was more overlap in diversity with samples from the tributaries of the Millers River, but for both types of bottoms there was not only more diversity in the tributaries, but also, by contrast with the Millers River, a tendency for high numbers of animals to be associated with the presence of many different types of animals.

Using mud samples taken with the Ekman grab as the basis for comparison, average numbers of animals per square foot at R-4, R-5, and R-9 were 101, 945, and 309 respectively. These may be compared with average values of 105 for the Ware River stations and 124 for the reservoir muds. The Oligochaeta were the predominant animals at R-4, R-5, and R-9. Midge fly larvae were predominant in the Ware River and the reservoir muds.

Table 13 shows several patterns which distinguish the Ware River and

Table 13. Number of Types of Benthic Animals Found in River Samples (January - August, 1971)

	Millers River Tributaries					Ware River		Millers River				Conn. River
Station	1	3	6	7	8	11	12	4	5	9	10	1
Animals												
Porifera	1	1	1	1		1						
Turbellaria	1	2		1		1			1			3
Oligochaeta	5	2	3	5	1	1	3	2	2	2	5	4
Hirudinea	1	1	2	4					3		6	2
Amphipoda		1	1	1	1	1	1					
Isopoda									1		1	1
Diptera	13	11	10	9	14	11	7	7	7	4	11	7
Other Insect Orders	30	42	44	34	16	31	15	3	5	1	16	2
Acari	4	7	2	5	4	9	2	1			1	2
Mollusca	1	3	2	1		2			1		3	5
Miscellaneous		3	4	2	1		3			1	1	1
Total	56	73	69	63	37	57	31	13	20	9	44	27

Figure 25. Number of Animals Per Square Foot at Riverine Stations

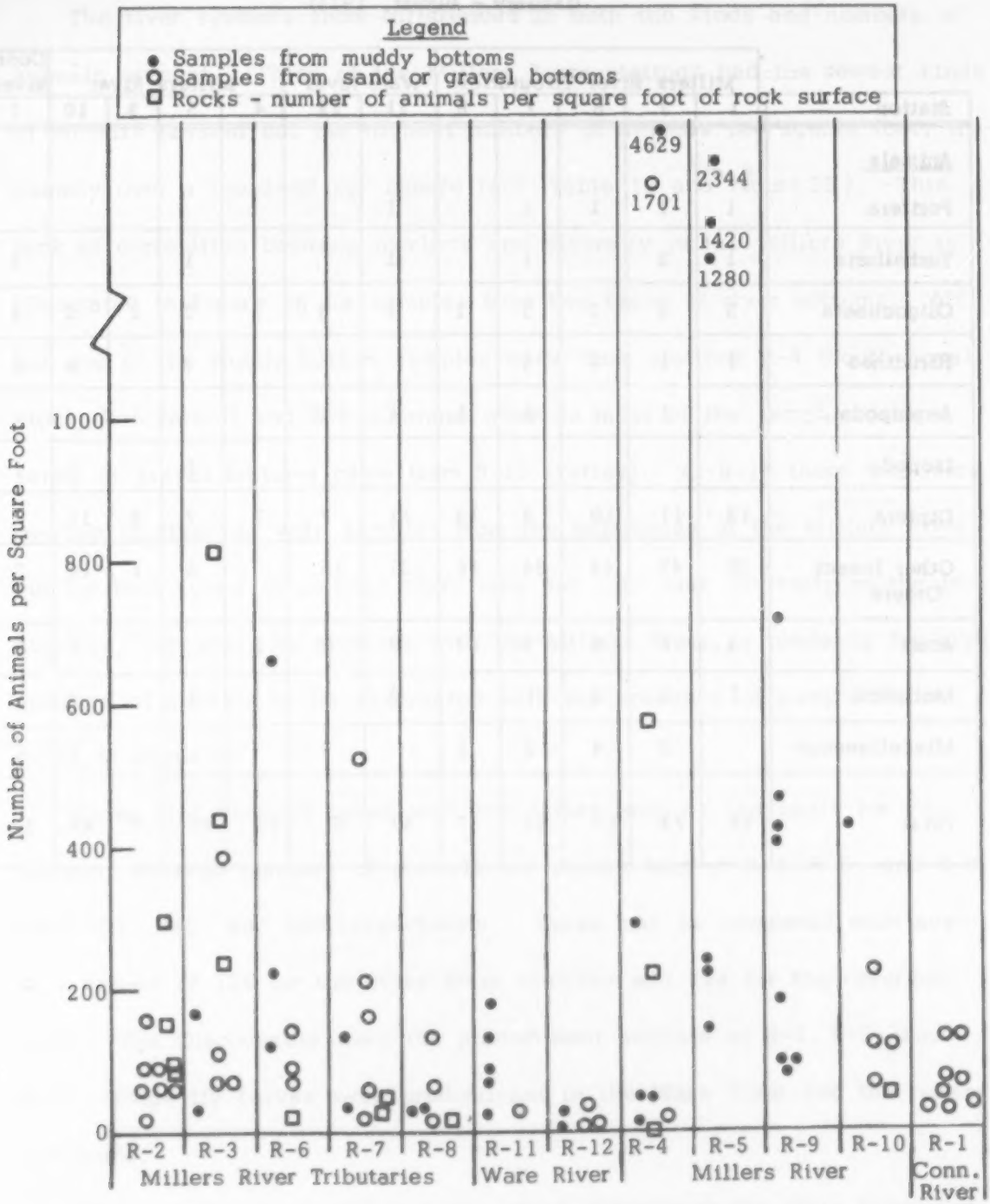
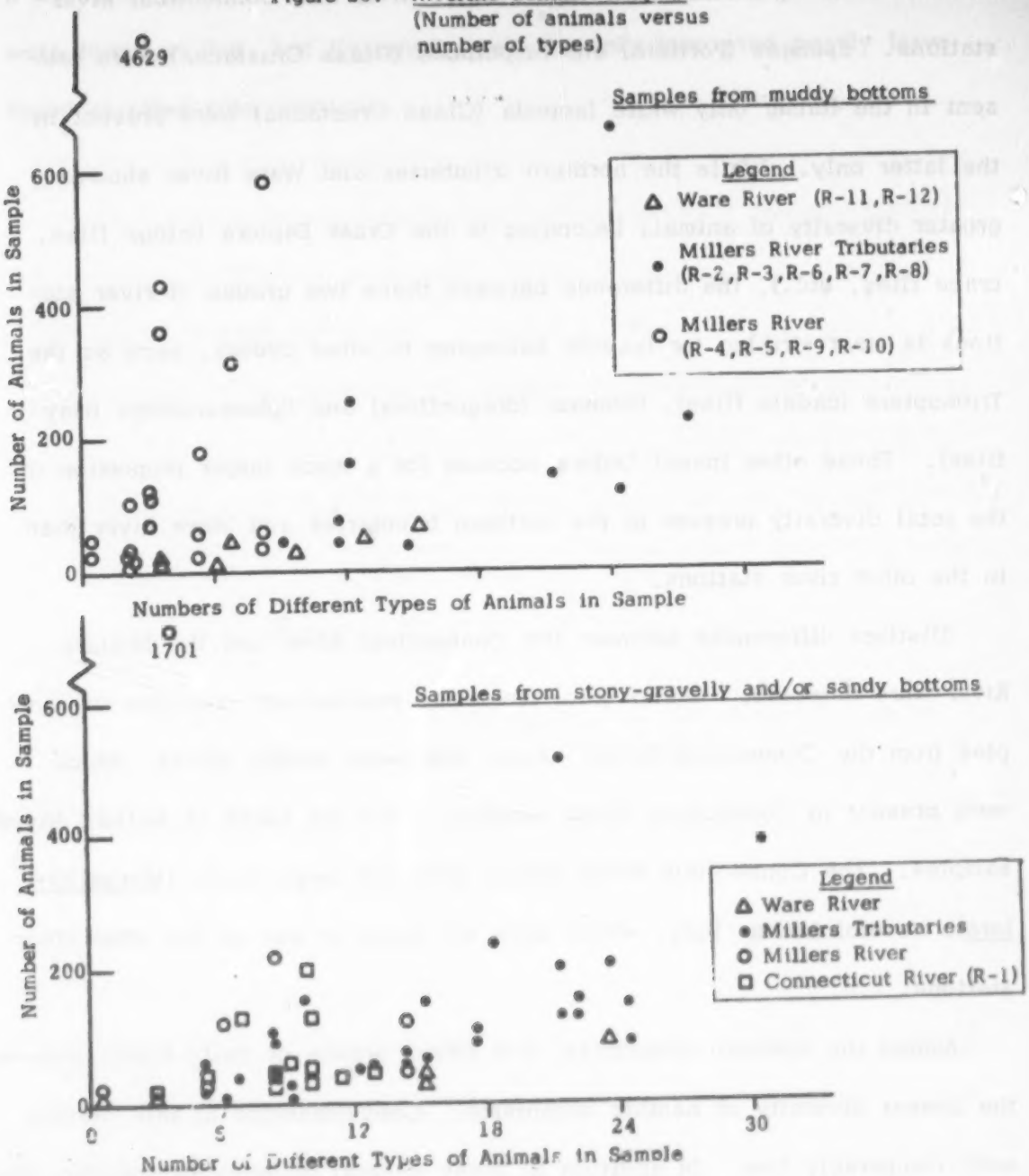


Figure 26. Riverine Benthic Samples (Number of animals versus number of types)



northern tributary stations from the Millers River and Connecticut River stations. Sponges (Porifera) and Amphipoda (Class Crustacea) were present in the former only while Isopoda (Class Crustacea) were present in the latter only. While the northern tributaries and Ware River showed a greater diversity of animals belonging to the Order Diptera (midge flies, crane flies, etc.), the difference between these two groups of river stations is most striking for insects belonging to other Orders, such as the Trichoptera (caddis flies), Odonata (dragonflies) and Ephemeroptera (mayflies). These other insect Orders account for a much larger proportion of the total diversity present in the northern tributaries and Ware River than in the other river stations.

Distinct differences between the Connecticut River and the Millers River were detected. Worms were never the predominant organism in samples from the Connecticut River. Also, burrowing mayfly larvae, which were present in Connecticut River samples, were not found in Millers River samples. The Connecticut River bottom also had large clams (Margaritifera), several inches long, which were not found at any of the other river stations.

Among the northern tributaries, R-8 (West Branch of Tully River) showed the lowest diversity of benthic organisms. Concentrations at this station were comparably low. In addition to these general differences, specific differences in the distribution of certain genera among the tributaries were observed. For example, Rhyacophila (caddis fly) was found only at station

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R-2. Two genera of burrowing mayfly larvae, Hexagenia and Ephemera were found at R-8, but Hexagenia was the only burrowing mayfly larva found at other river stations.

B. Chemical Data

Most chemical parameters exhibited a broad annual pattern which was generally predictable. For example, in the rivers, a decrease in some parameters was observed during high flows in the spring, and an increase with decreasing flows later in the year. This type of pattern was not so obvious in the reservoirs. Substances readily associated with photosynthetic activity in both riverine and reservoir systems also varied in an expected manner. Annual pattern of individual parameters will be discussed in more specific detail in the following sections. Refer to Appendix 1 for methods.

A number of parameters were either never or very infrequently detected and, thus, will not be discussed. These include: detergents (MBAS), aluminum (Al), arsenic (As), barium (Ba), boron (B), cadmium (Cd), hexavalent chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), selenium (Se), silicon (Si), silver (Ag), uranyl ion (UO_2^{2+}), cyanide (CN^-), and fluoride (F^-). Of these, it is interesting to note that most of the few incidences of Cd, Co, and Cu occurred in the Millers River tributaries and, thus, were probably derived from natural rather than human sources.

Sulfate sulfur (SO_4-S) was present in all samples, but exhibited no annual patterns. There was little significant variation between riverine and reservoir stations; riverine samples ranged from 2.0 to 8.0 µg/ml while reservoir samples ranged from 1.5 to 5.0 µg/ml of SO_4-S. No further discussion will be given this parameter.

For the discussion of chemical parameters, six individual sampling stations have been selected as being representative of all others (Figures 5, 6 and 7).

They are as follows:

(1) Connecticut River (R-1)

This station is reasonably unique among the rivers and stands alone.

(2) Millers River near Athol (R-5)

This station is characteristic of all the Millers River stations (R-4, R-9 and R-10).

(3) Lawrence Brook (R-6)

This station is quite representative of the other tributaries to the Millers River, i.e. R-2, R-3, R-7, and R-8. Of these, only R-8 (West Branch of Tully) is somewhat different; the difference is one of magnitude and not kind, in that R-8 tends to have values on most parameters lower than the other streams.

(4) Quabbin Reservoir (Q-1)

This station is representative of the "outside" reservoir stations which also include Q-2, Q-3, Q-6, and Q-8. Q-1 was sampled at the surface and at a depth of 10 meters; the values indicated in the following graphs are averages of the two depths.

(5) Quabbin Reservoir (Q-4)

This station is representative of the "inside" reservoir stations which also include Q-5, Q-7, and Q-9.

(6) Wachusett Reservoir (W-2)

This station was selected to be representative of the reservoir as a whole primarily because of its central location. While differences were found between various parts of the reservoir, one station was chosen for simplicity of presentation; differences between sites were not outstanding.

The parameters which are to be discussed for these six representative locations are alkalinity, chemical oxygen demand, total hardness, chloride, ammonia nitrogen, total phosphorus, sodium, potassium, iron, manganese, zinc, mercury, and carbon chloroform extract (CCE).

Our contract did not require us to measure aluminum, cobalt, silicon, sodium and potassium; analyses were conducted by the subcontractor because of interests in these parameters. Secondly, many of the parameters were measured at frequencies greater than those specified in the contract. Finally, several parameters of total and dissolved nitrogen and phosphorus were measured. However, discussions are based on total phosphorus and ammonia nitrogen.

Alkalinity

The data for alkalinity are shown in Figures 27 and 28. It is immediately apparent that alkalinity is very low in Quabbin and Wachusett Reservoirs and the tributary streams (R-6). Wachusett Reservoir (W-2) is most similar to Quabbin (Q-4), while Lawrence Brook (R-6) is almost identical to Quabbin (Q-1). It would be unwise to attach any significance to the variations of alkalinity with time in these particular systems since such low alkalinities are undoubtedly accompanied by a low buffer capacity; thus, relatively small changes in conditions could result in pH changes of a magnitude sufficient to alter the alkalinity as shown.

The highest alkalinities were obtained in the Connecticut River (R-1), being about an order of magnitude higher than those in the reservoirs or tributary

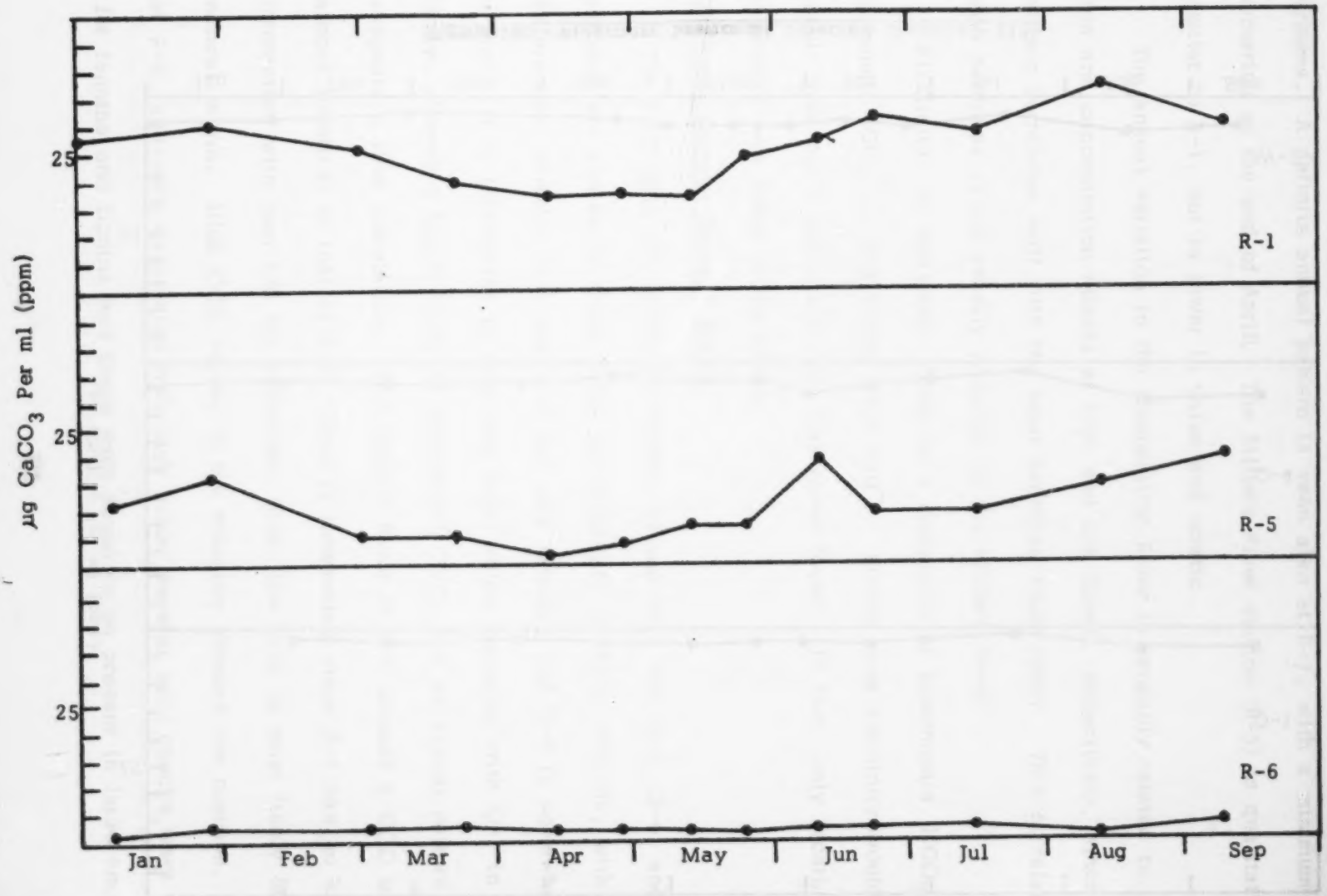


Figure 27. Alkalinity Levels at Selected Stations, 1971

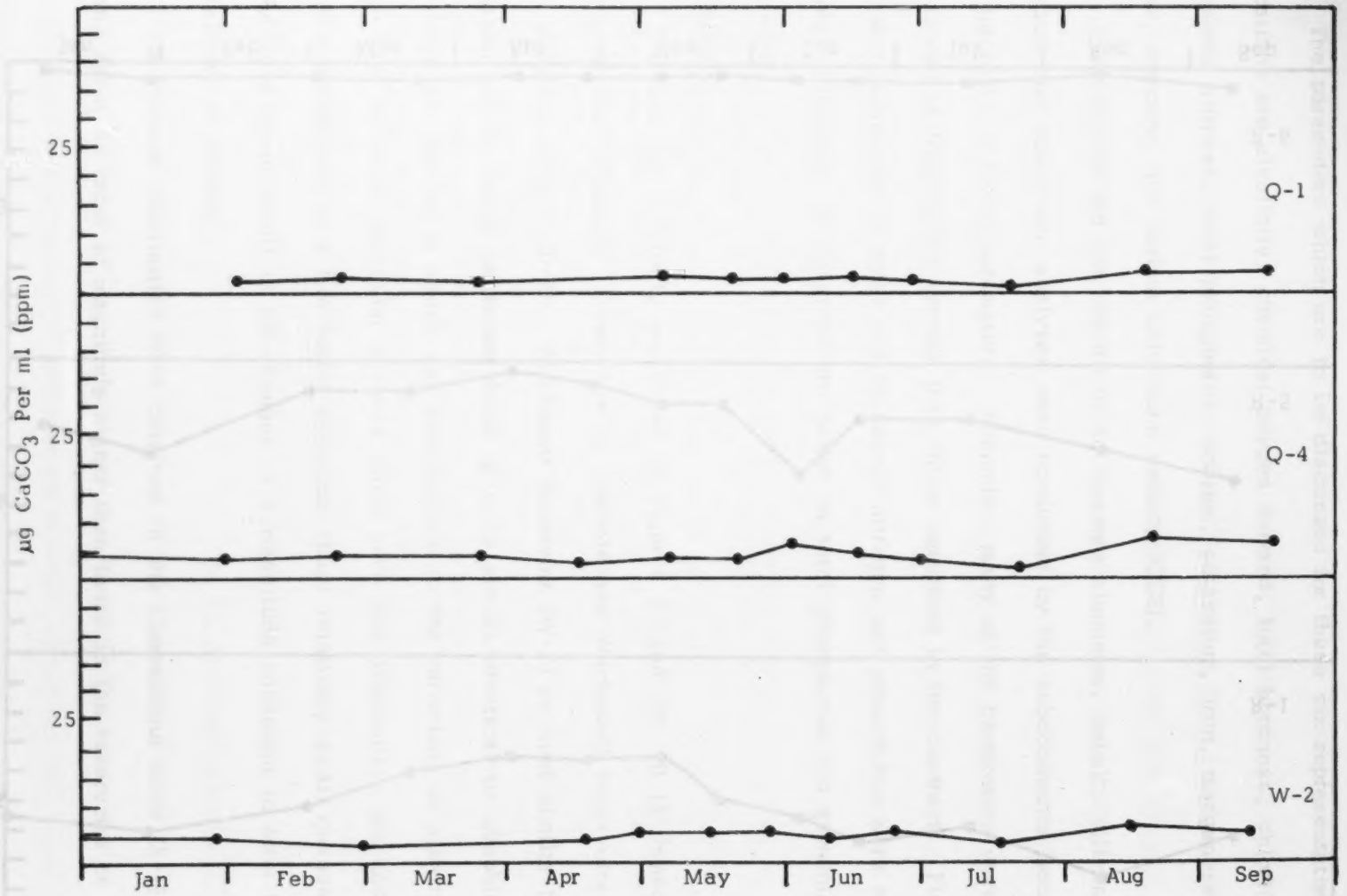


Figure 28. Alkalinity Levels at Selected Stations, 1971

streams. A definite annual pattern is seen also at R-1, with a minimum occurring at the end of April. The Millers River station (R-5) is qualitatively similar to R-1, but is lower in value and erratic.

The annual variation in the Connecticut River is probably related to dilution and concentration effects at high and low flows, respectively, since the pattern correlates well with the total hardness (vide infra). This correlation with hardness is not readily possible in the Millers River.

Alkalinity, as measured, could be a composite of bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), and strong base (OH^-). Strong base alkalinity would only result from man's activities; this was never found. In fact, only bicarbonate alkalinity was found in all cases.

Chemical Oxygen Demand (COD)

The COD data are shown in Figures 29 and 30. The Q-1, Q-4, and W-2 patterns are similar to those found for alkalinity at these stations, with subtle differences; namely, Q-1 and W-2 are very similar, and Q-4 is somewhat higher. It is interesting to note that R-6, which compared with Q-1 in alkalinity, showed a higher (order of magnitude) COD, and an annual pattern that suggests a flow correlation. The Millers River at R-5 showed a COD pattern almost identical to that at R-6. This is interesting since R-6 has no known interaction with man and his activities; thus, the COD is most likely of a natural origin. High COD values in the tributary streams are common, except at R-8, and were associated with high color; several spot checks were made for tannins and lignins and these were found to be present in large amounts.

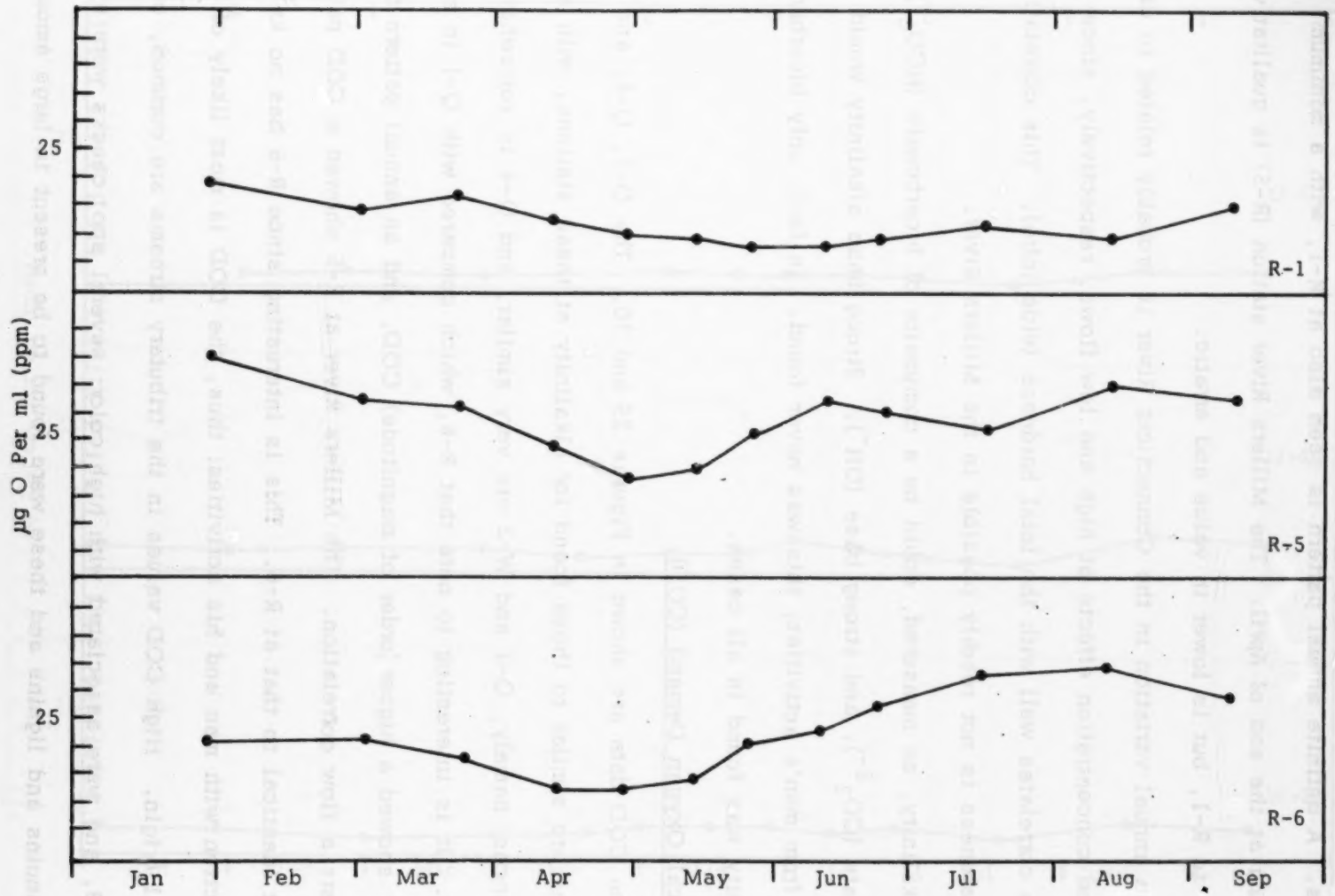


Figure 29. COD (Chemical Oxygen Demand) Levels at Selected Stations, 1971

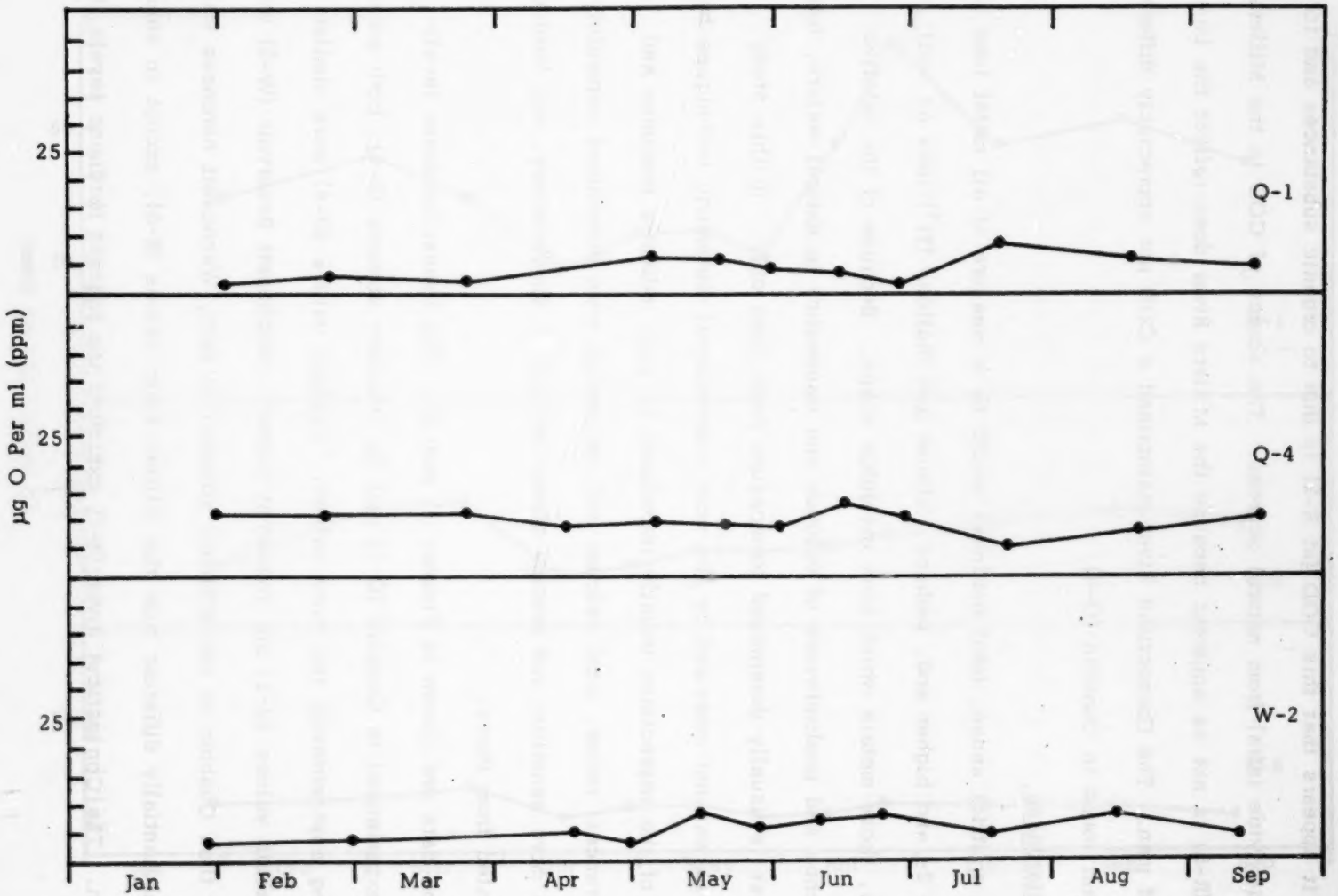


Figure 30. COD (Chemical Oxygen Demand) Levels at Selected Stations, 1971

Thus, it appears that this COD (at R-6) is due to organic substances and to ammonia (vide infra) from natural sources. The source of COD in the Millers River (R-5) is not as apparent because the Millers River does reflect the impact of man. The Connecticut River maintained a COD not appreciably different from that found in Quabbin (Q-4).

Total Hardness

In a strict sense, total hardness would be a measure of all metal ions of charge 2+ and higher and, perhaps, lithium and thallous (Tl^{+}) ions as well; that is, those metals which form insoluble soaps. Because of the relative abundance and predominance of calcium and magnesium in natural waters, total hardness is usually determined to measure these ions only. In this study, hardness was not measured by the more conventional titrimetric techniques because of the imprecision usually introduced by poor indicator response and interferences; rather, total calcium and magnesium were determined separately by the more sensitive and precise atomic absorption spectroscopy, and hardness calculated from these.

The data are shown in Figures 31 and 32. The lowest hardness levels were experienced in Quabbin (Q-1) and the tributary streams (R-6), both areas showing approximately the same values. Quabbin values (Q-4) were similar to Quabbin values (Q-1) but somewhat higher. Wachusett Reservoir (W-2) was higher than Quabbin or the tributary streams; in fact, Wachusett hardness was not substantially different from the Millers River values (R-5), except in annual pattern. The Connecticut River (R-1) exhibited the highest hardness levels, the

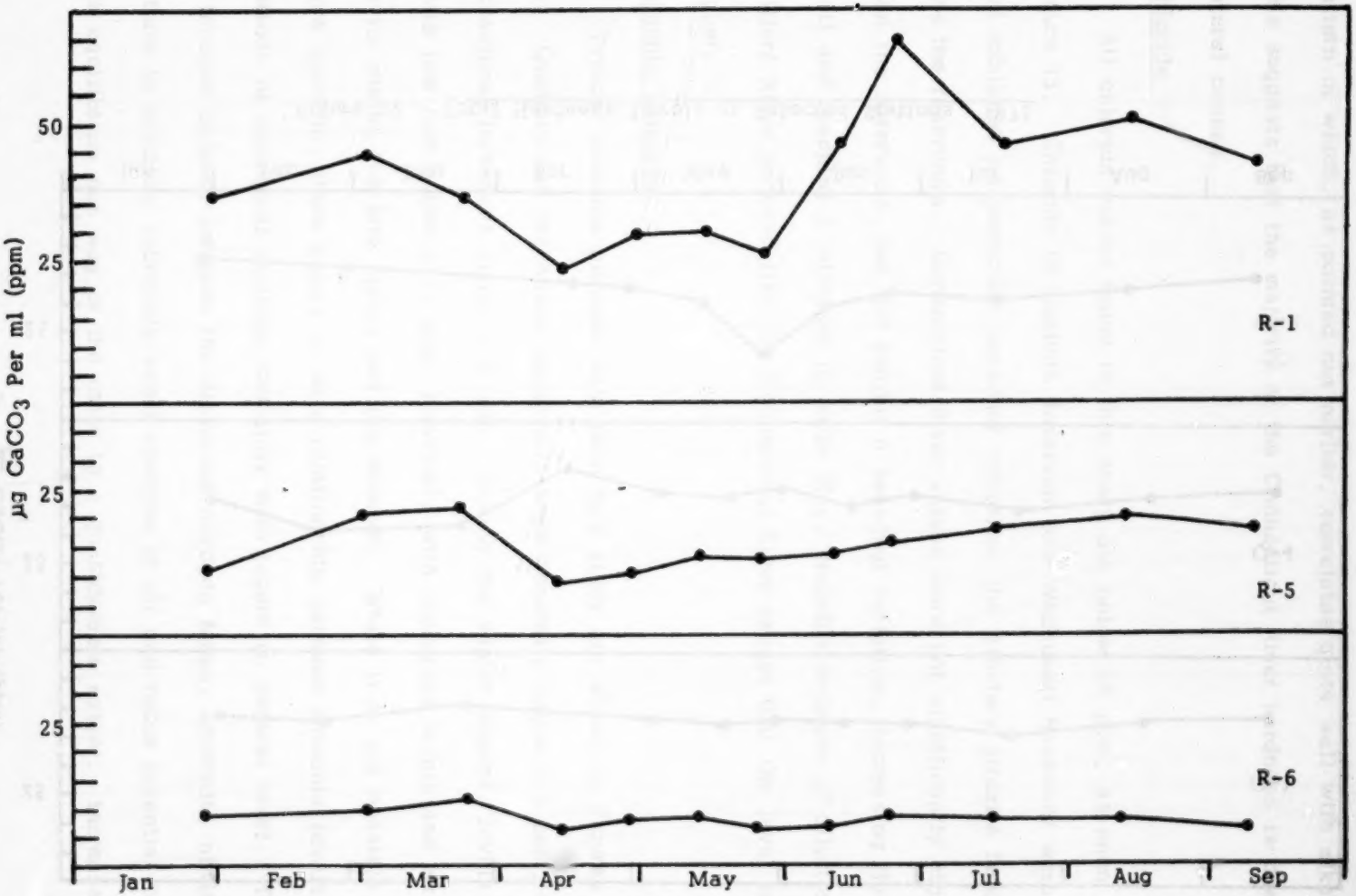


Figure 31. Total Hardness Levels at Selected Stations, 1971

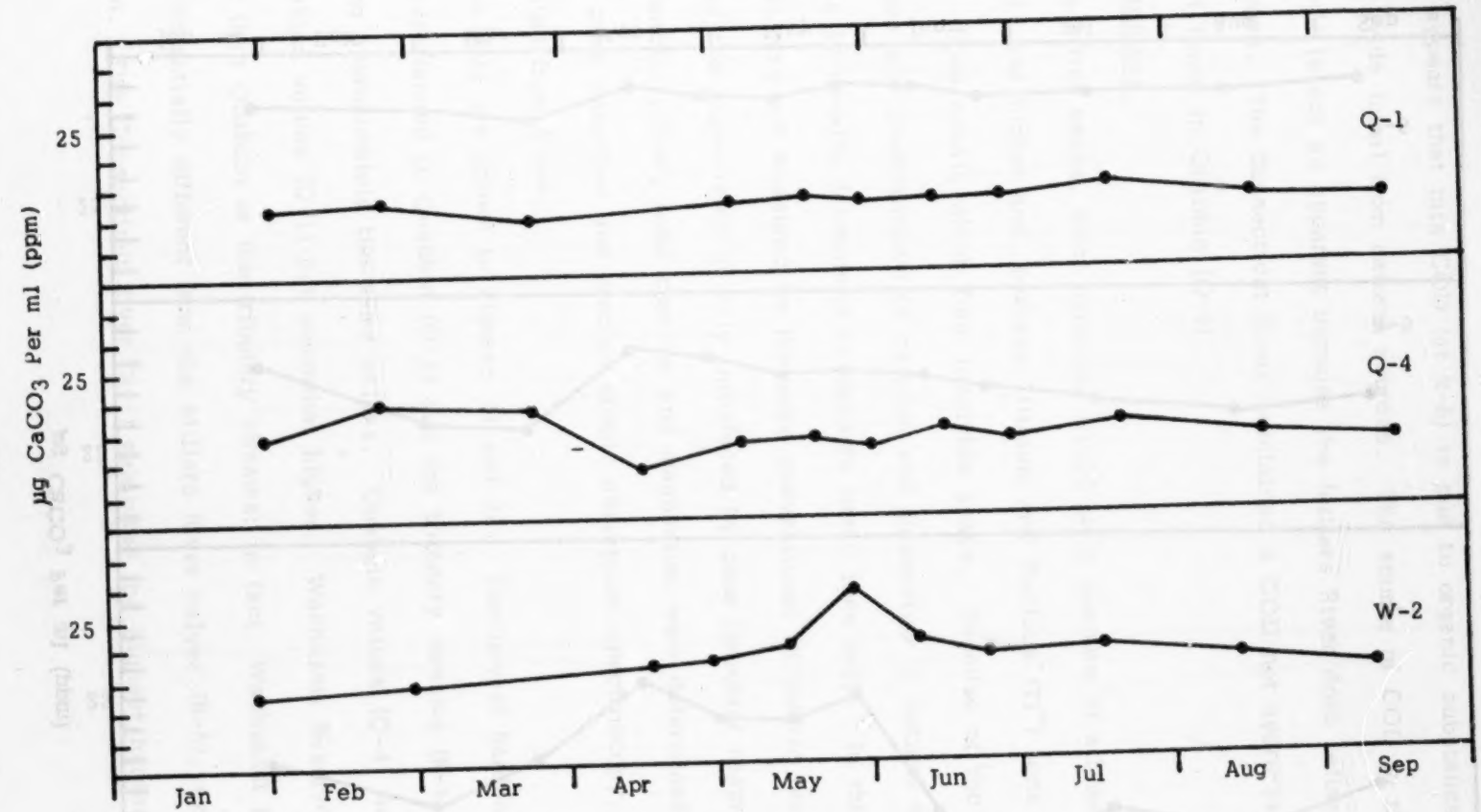


Figure 32. Total Hardness Levels at Selected Stations, 1971

pattern of which, as pointed out earlier, correlates quite well with alkalinity. This suggests that the majority of the Connecticut River hardness is due to natural causes.

Chloride

All chloride values found in this study are below 25 ppm, as seen in Figure 33. Chloride in Quabbin Reservoir and Wachusett Reservoir were low and exhibited no particular seasonal variation; the tributary streams behaved like the reservoirs. Connecticut River values were not significantly higher than the reservoirs, but did exhibit a seasonal variation, decreasing through April and reaching a minimum in early May, probably because of dilution. The Millers River behaved like the Connecticut River except that the level was higher.

Ammonia Nitrogen

Typical ammonia nitrogen data from this study are shown in Figures 34 and 35. Quabbin and Wachusett Reservoirs were generally below 0.5 ppm, with occasional increases above 0.5 ppm. During the winter months, levels were quite low (not below 0.01 ppm, however), with increased levels and erratic behavior during the late spring and the summer. While it is not possible to be more specific, there seems to be a relationship between ammonia levels and periods of biological activity, certainly with regard to general level. There is a tenuous balance between the dissolved nitrogen forms, ammonia, nitrite, and nitrate in solution; relatively small changes in pH and redox potential can shift the equilibrium one way or the other to a considerable extent. Increased surface

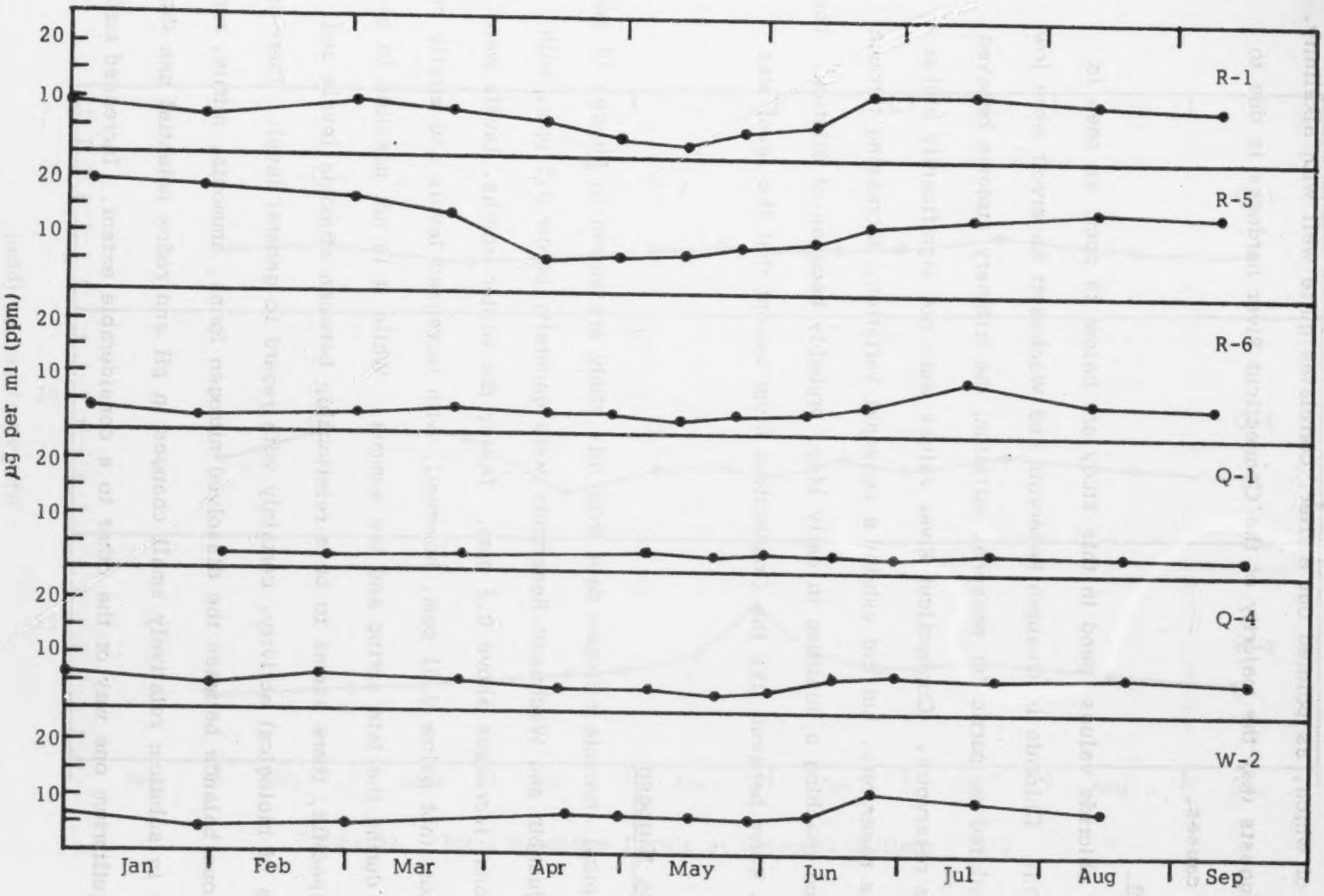


Figure 33. Chloride Levels at Selected Stations, 1971

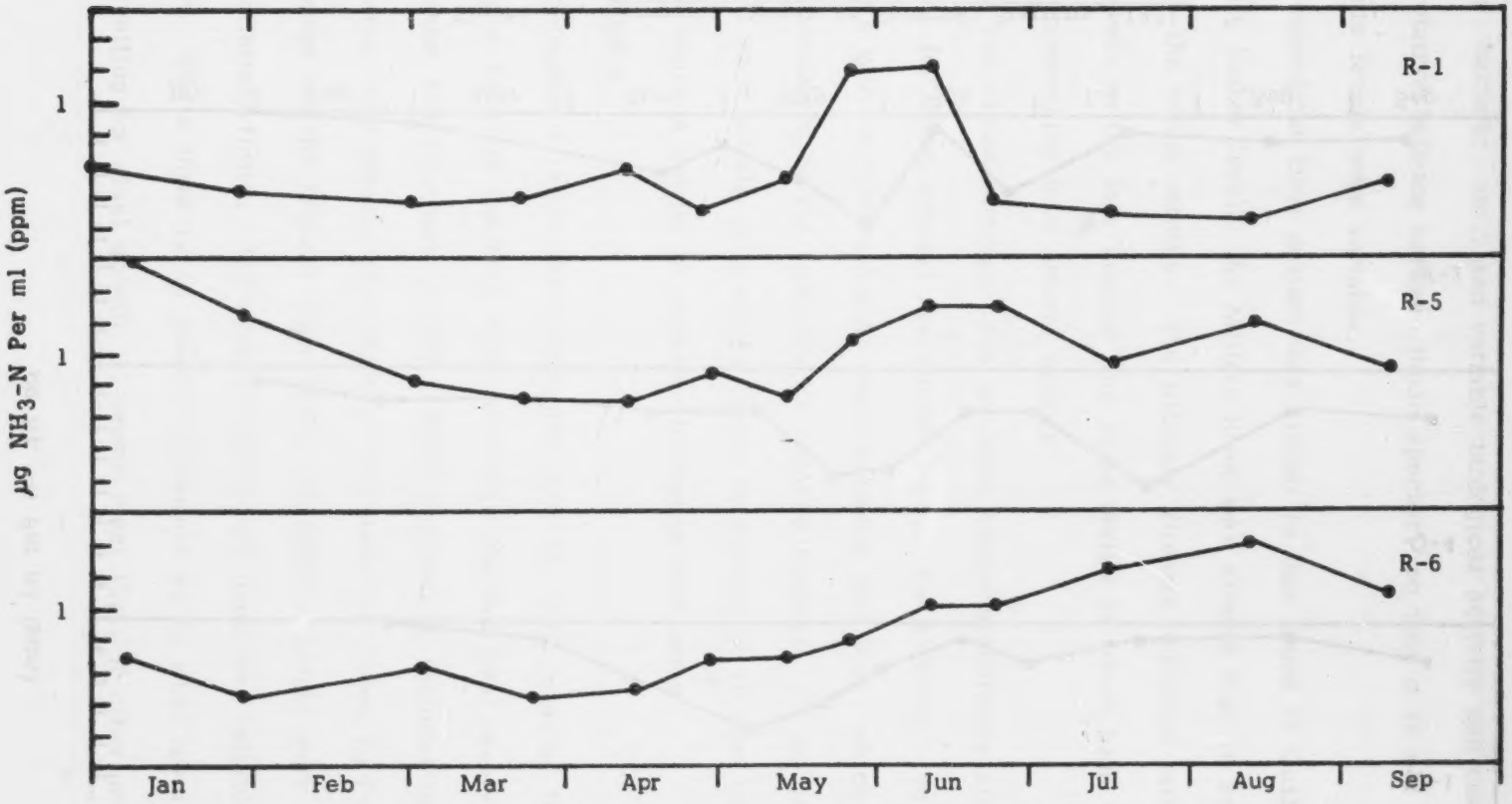


Figure 34. Ammonia Levels at Selected Stations, 1971

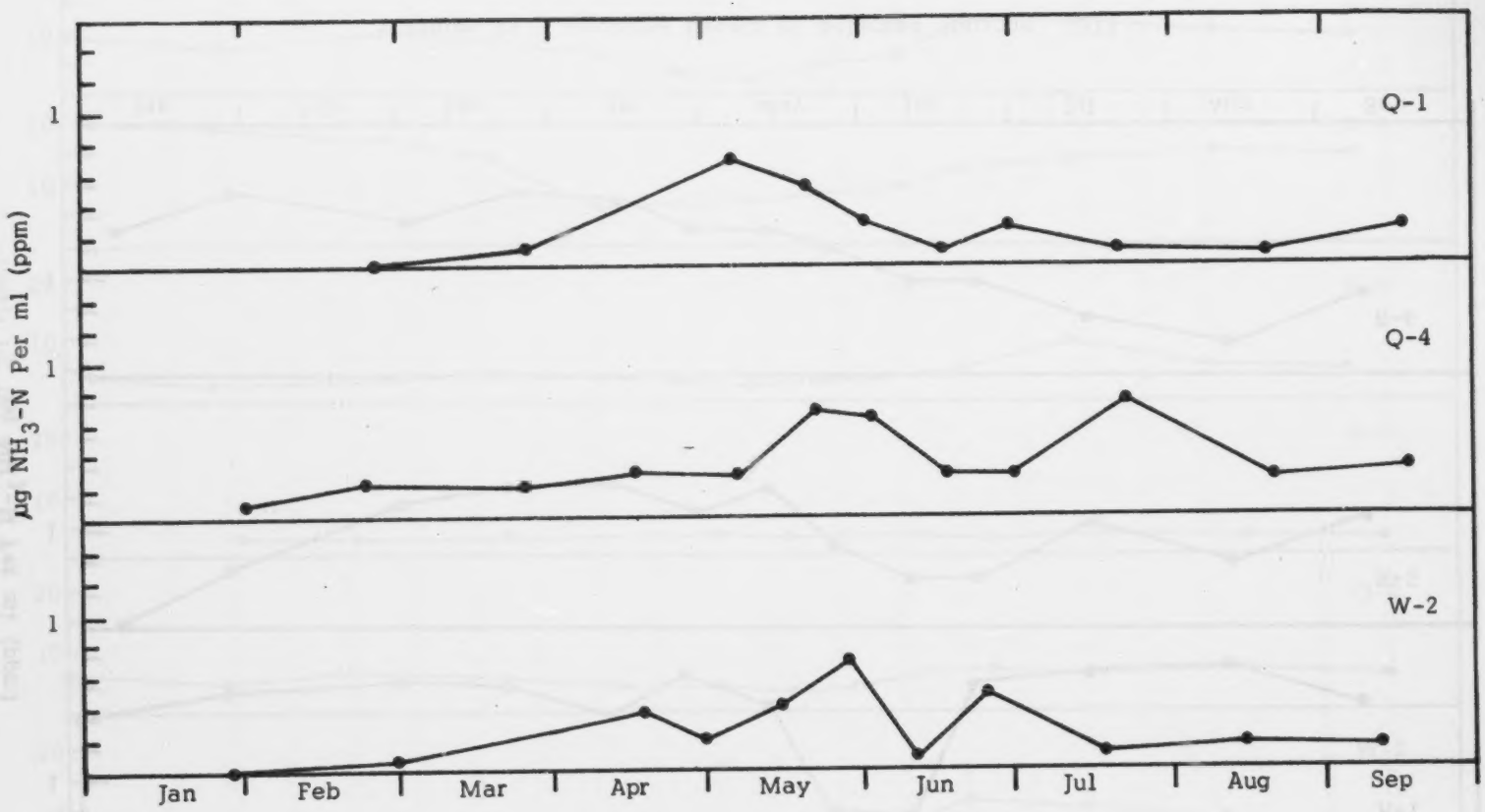


Figure 35. Ammonia Levels at Selected Stations, 1971

area (algae, bacteria, etc.) and variable biological activity can combine to shift the relative balance between these species, so that it is not surprising that ammonia levels were variable.

The Connecticut River pattern was similar to that found in Quabbin (Q-4) with slightly higher levels; the Millers River was always high in ammonia, even during the winter months. The tributary streams exhibited rather high ammonia levels in the late summer (the same period in which high colors were observed), presumably from natural causes.

Nitrate and nitrite nitrogen have not been shown graphically since the general patterns for these species are similar to that for ammonia. In general, nitrite levels were relatively higher when ammonia was high, which indicates conditions conducive to the formation of reduced species. In no case did any water tested have nitrate plus nitrite levels in excess of 10 ppm total, the level above which a danger of methemoglobinemia may occur.

Total Phosphorus

Total phosphorus rather than particular species, was selected for discussion because, from an algal point of view, it represents the total reservoir of nutrient, for short and long-term supply. Total phosphorus includes orthophosphate, polyphosphates, and organic phosphorus. The data are shown in Figure 36.

Except for the Millers River (R-5), phosphorus levels were reasonably low, but definitely finite. The analysis procedure used was reliable down to 0.01 ppm P. While there is no general agreement as to what level of phosphorus is limiting for algal growth, it seems clear that, if other growth factors

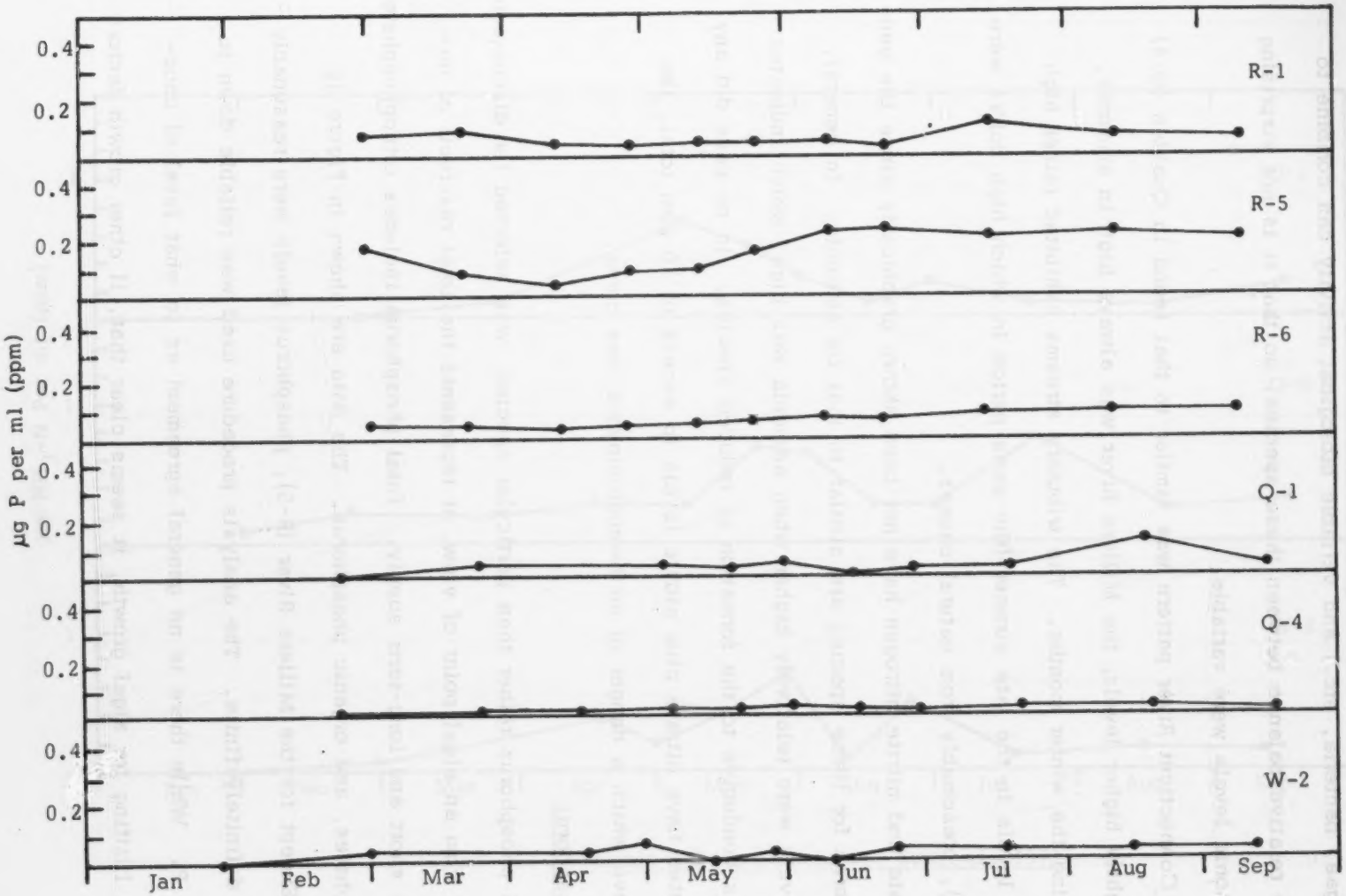


Figure 36. Total Phosphorus Levels at Selected Stations, 1971

are favorable, phosphorus levels in excess of 0.01 ppm will support algal growth and even blooms. Thus, all waters sampled in this study could support algal populations in excess of those found, based on the phosphorus level. That frequent blooms and high algal levels are not often observed suggests that some other growth factor, or factors, are limiting; in the waters observed in this study, the general lack of available carbon (as evidenced by the low alkalinities) probably aids in limiting algal growth.

The phosphorus levels in "outside" waters of Quabbin are higher than those found in "inside" waters of Quabbin. The Millers River had the highest phosphorus levels of all waters, values as high as 0.2 ppm being common.

Sodium

While sodium was not called for in the project contract, it was measured because of its requirement in living systems. It has proved to be an instructive parameter. None of the sodium levels observed were high enough to impart any taste to the water.

The influence of man and his activities is clearly seen from a study of Figure 37. Both the Connecticut (R-1) and Millers (R-5) Rivers show marked increases in sodium during the early spring, no doubt due to the introduction of road salt. These levels drop when the freshet flow occurs, due to dilution. The level recovers from this dilution and tends to rise, then level off, during the summer. The Millers River remained moderately high and erratic, probably indicating that man's activities may have a more obvious impact on this river.

Wachusett Reservoir (W-2) showed a similar effect, except that the

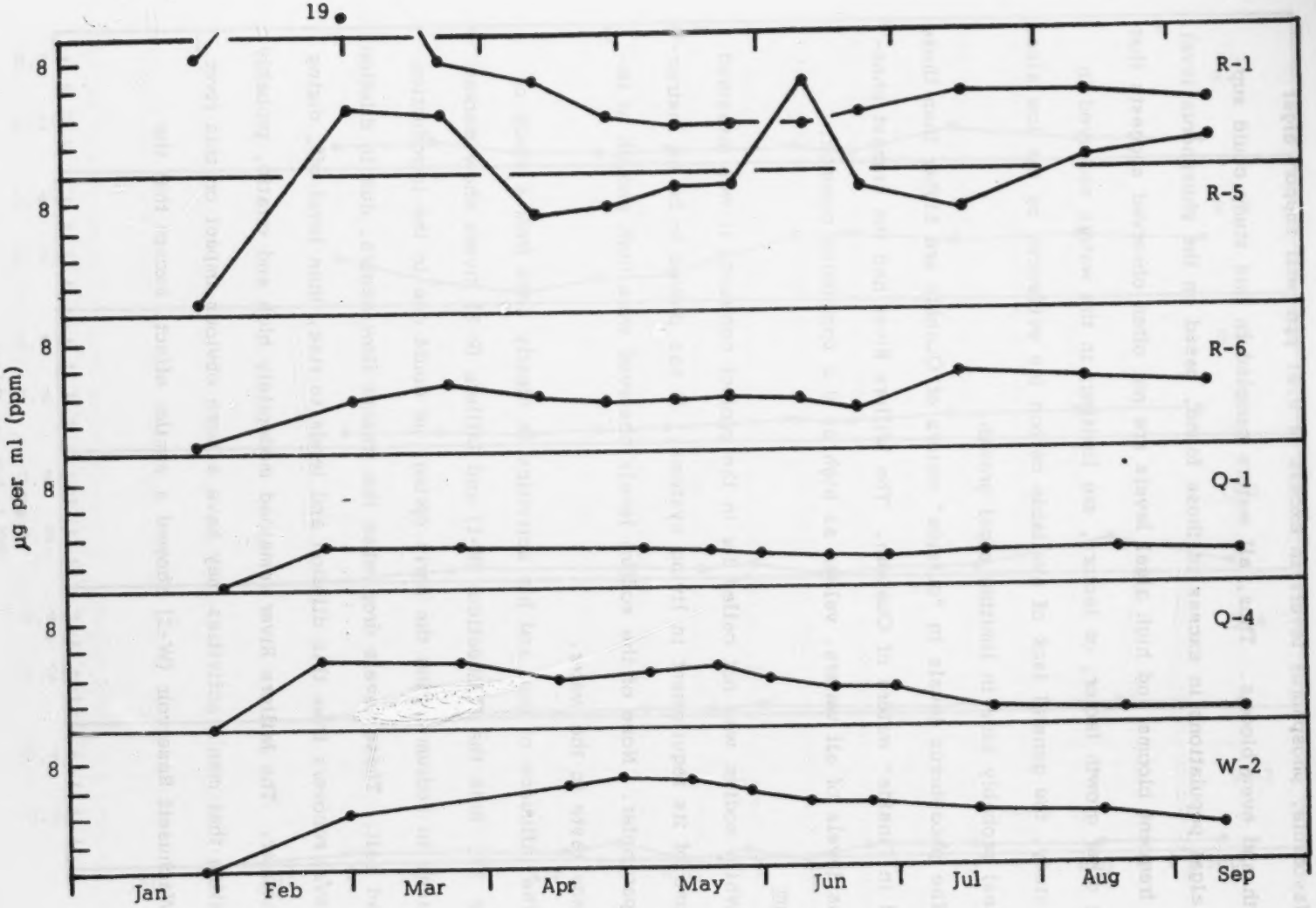


Figure 37. Sodium Levels at Selected Stations, 1971

maximum did not occur until April-May, and it was more gradually approached. In Quabbin and the tributary streams, sodium seems to be low in the winter and higher in the spring through fall months, but no marked changes were observed.

Potassium

Potassium levels, shown in Figure 38, were measured because of the need for potassium by living systems. They are included here primarily to illustrate that, generally, potassium did not vary in the same way as did sodium, especially in the Connecticut River. This supports the contention that much of the sodium observed was not due to natural causes, but was a result of human activity.

Total Iron

Some concern has been expressed about the possible introduction of iron (and manganese, etc.) into Quabbin and Wachusett Reservoirs upon the introduction of Connecticut River waters into Quabbin. Figure 39 illustrates the potential direct sources of iron. Virtually all iron found was present as the oxidized iron (III).

Quabbin "outside" waters and Wachusett Reservoir were almost free of detectable iron; Quabbin "inside" waters frequently showed moderate levels approaching the 0.3 ppm (filterable) level.

The Connecticut River exhibited fairly high iron levels until the end of April after which the level was virtually nil. In contrast, both the Millers River and the tributary streams consistently exhibited high iron, the level of

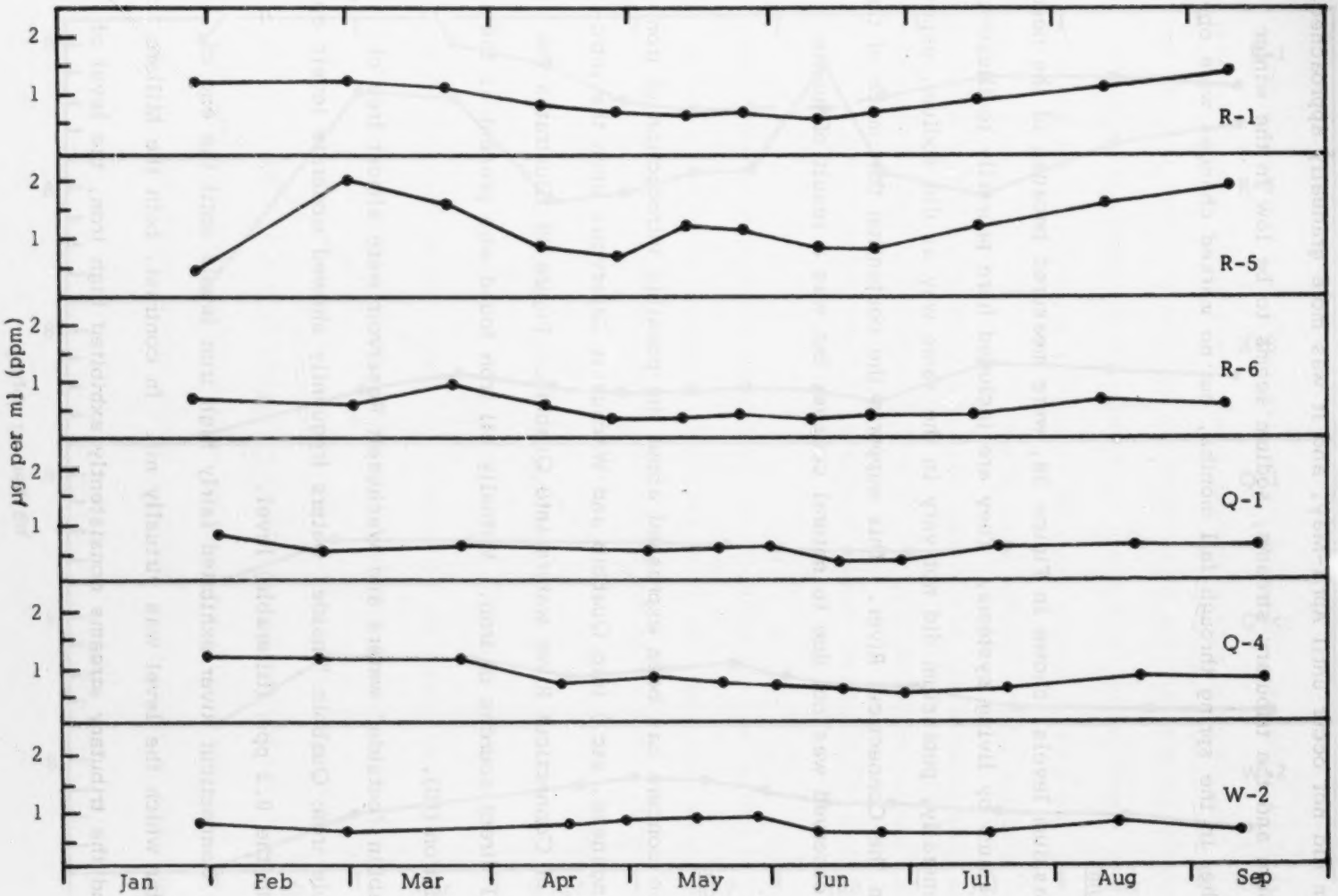


Figure 38. Potassium Levels at Selected Stations, 1971

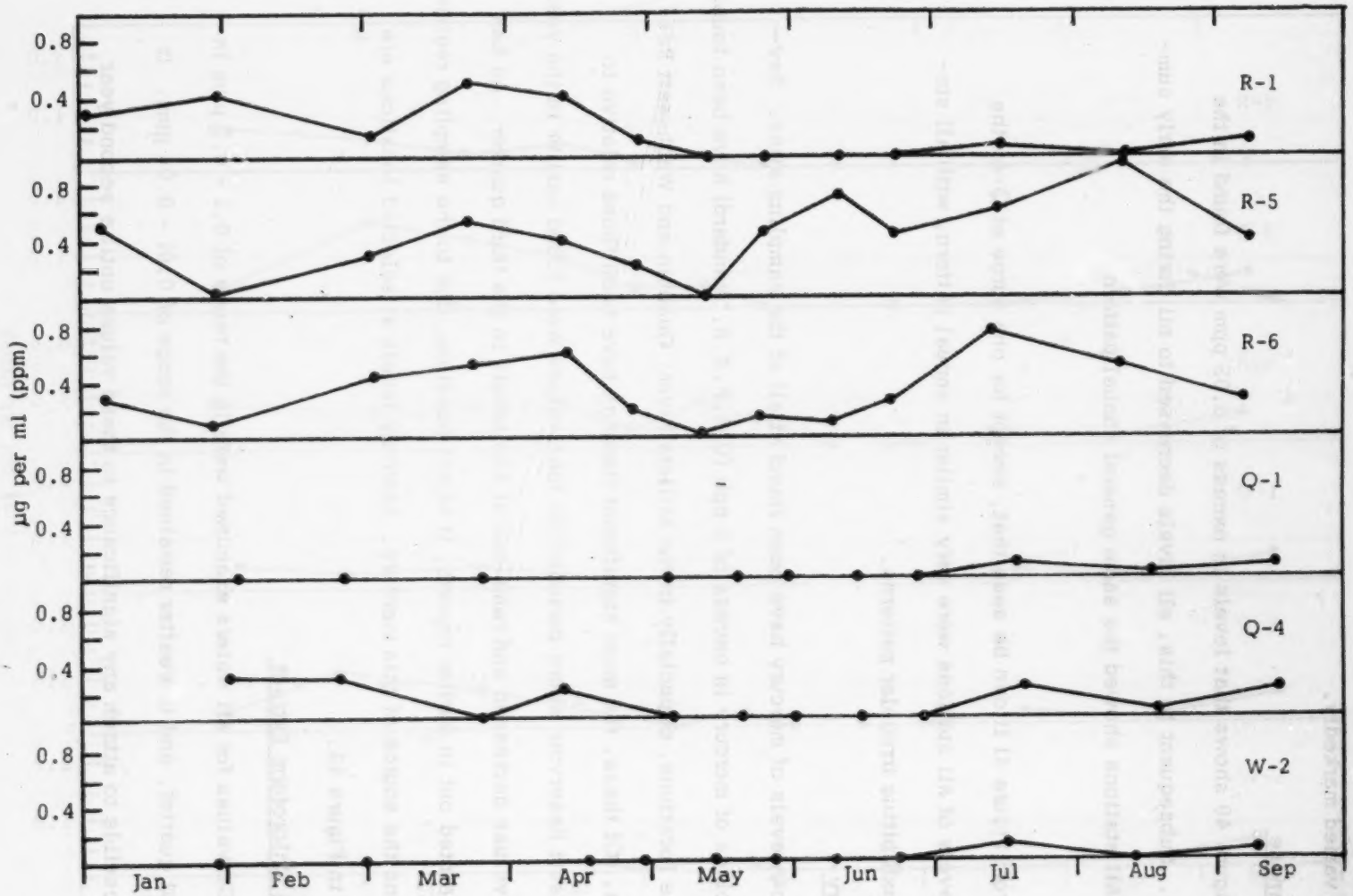


Figure 39. Total Iron Levels at Selected Stations, 1971

which varied markedly.

Manganese

Figure 40 shows that levels in excess of 0.05 ppm were found in the spring. Subsequent to this, all levels decreased to nil during the early summer. All stations showed the same general annual pattern.

Zinc

From Figure 41 it can be seen that, except for one surge at Q-4, the zinc levels of all stations were very similar in annual pattern, with all stations exhibiting irregular patterns.

Mercury

Low levels of mercury have been found at all of the sampling sites. Several spikes of mercury in excess of 5 ppb (U.S.P.H.S. standard) have been found at some locations, especially in the Millers River, Quabbin and Wachusett Reservoirs. Of these, the most significant findings have been those relative to Wachusett Reservoir where periodically high values were found earlier in the year. These values decreased and remained at low levels in the third quarter. As has been pointed out in earlier reports, it is not possible, due to the sampling regimen, to define the source of this mercury. Mercury levels at selected locations are shown in Figure 42.

Carbon Chloroform Extract

CCE values for all waters examined were in the range of 0.1 - 0.2 ppm in the first quarter, and thereafter remained in the range of 0.01 - 0.04 ppm. It is impossible to attach any significance to these values until a second year

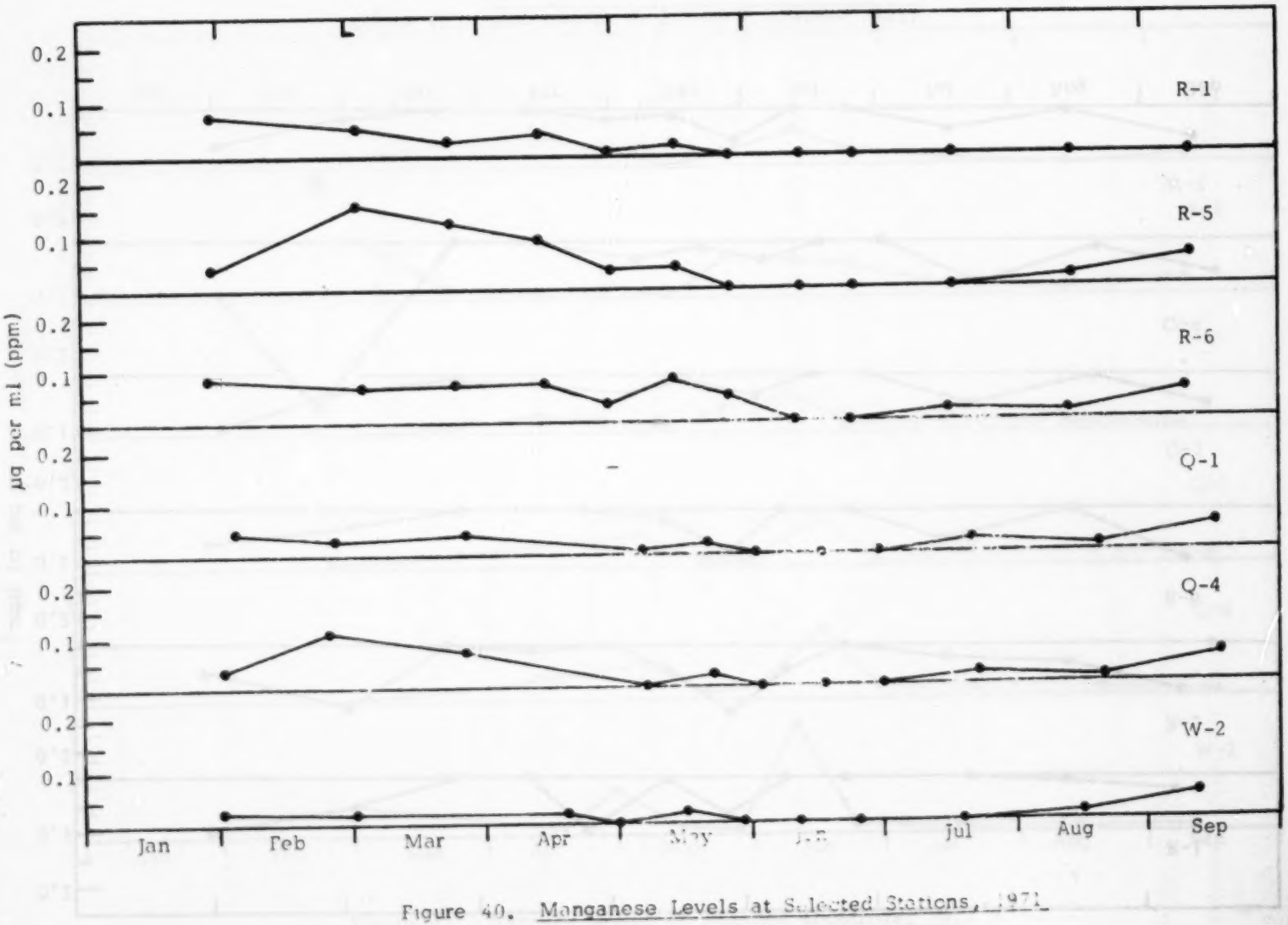


Figure 40. Manganese Levels at Selected Stations, 1971

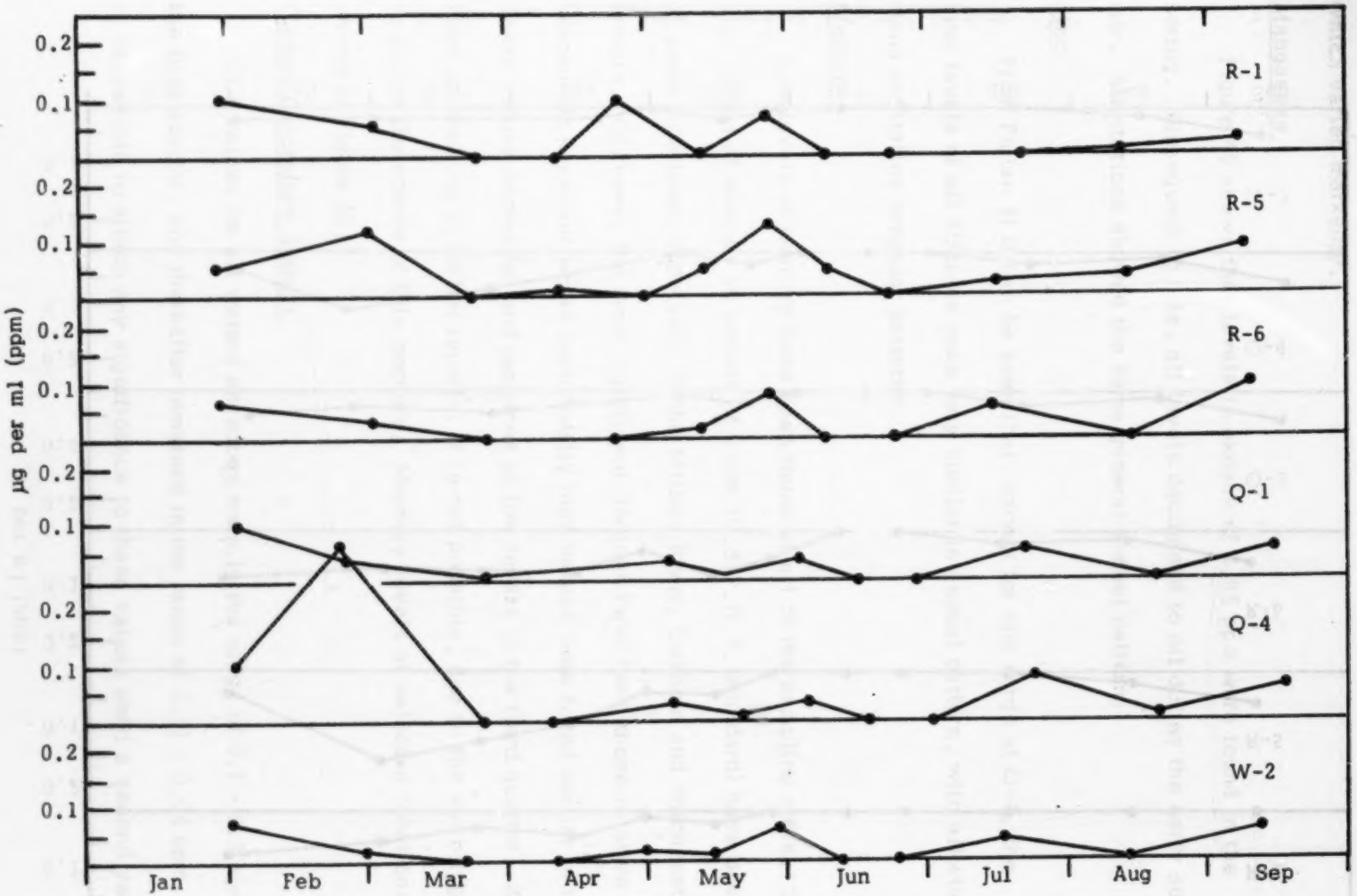


Figure 41. Zinc Levels at Selected Stations, 1971

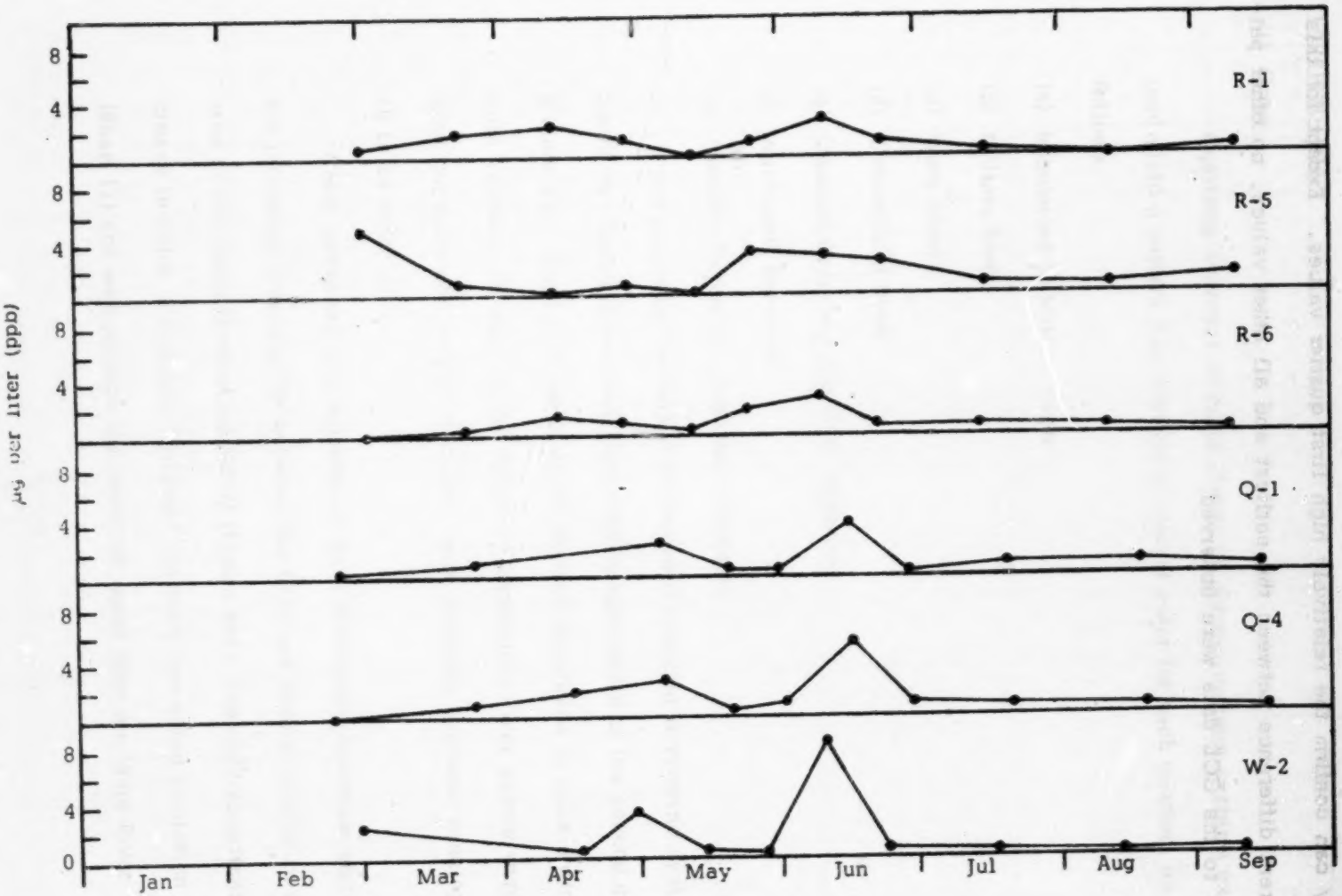


Figure 42. Mercury Levels at Selected Locations, 1971

study can confirm the relatively high first quarter values. Except for this apparent difference between the earliest and all other values, no other patterns to the CCE data were observed.

C. Physical Data

(1) Color

Quarterly averages of color (Table 14) for the various systems examined yield a pattern from highest to lowest color for each quarter, as follows:

(a) tributaries to Millers River

(b) Millers River

(c) Ware River

(d) Connecticut River

(e) Quabbin Reservoir ("inside" stations)

(f) Wachusett Reservoir

(g) Quabbin Reservoir ("outside" stations)

Color generally decreased or remained constant in riverine systems during the first quarter, and increased in the middle of the second quarter (Figure 43). Most riverine stations showed decreases in color during the third quarter. Of all riverine waters, Connecticut River waters were the most constant with respect to color, with quarterly averages ranging from 20 to 25 color units.

Color increased only slightly at most Wachusett Reservoir stations, but increased dramatically between the first and second quarter in the area of the Route 12 crossing (W-1) (Figure 44). The only significant increase in color in Quabbin "outside" stations was noted at station Q-6 (Shaft 12) and was perhaps the result of water from the Ware River

Table 14-A. Summary of Physical Data

		Color Pt.-Co. Units			Specific Conductance Micromhos/cm			Dissolved Oxygen mg/l			pH			Turbidity Hach J.T.U.			Turbidity Spec. 20 J.T.U.	
Quarter		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
Quabbin "Outside"	No. of Readings	28	41	27	28	41	27	13	41	27	28	41	27	7	44	27	28	20
	Range	1.0 6.0	2 10	5 5	33 59	40 44	42 46	11.0 14.6	9.0 12.6	6.4 10.8	5.8 6.4	6.0 6.7	0.3 7.1	0.3 0.8	0.3 0.8	0.6 1.0	4 4	4 8
	Average	3	4	5	44	42	43	13.8	11.2	8.6	6.2	6.4	6.6	0.5	0.5	0.8	4	4
Quabbin "Inside"	No. of Readings	25	37	19	25	36	19	10	35	19	25	36	19	7	36	19	25	19
	Range	3 35	5 65	5 25	37 73	41 55	44 53	10.3 13.9	7.6 12.1	6.0 8.5	4.6 6.4	5.4 6.7	6.3 7.0	0.7 1.0	0.5 1.0	0.7 2.0	4 26	4 30
	Average	15	20	12	54	48	48	12.5	10.2	7.9	6.1	6.2	6.7	0.9	0.8	1.0	10	16
Wachusett	No. of Readings	23	36	18	25	36	18	17	36	18	25	36	18	4	36	18	25	24
	Range	1 17	3 40	5 10	36 108	60 98	47 79	12.4 13.8	9.3 12.8	6.8 9.4	4.8 6.5	6.2 7.0	6.4 7.3	0.4 0.9	0.3 1.0	0.5 0.8	4 16	4 22
	Average	4	11	7	58	72	67	13.1	11.0	8.4	6.0	6.6	6.8	0.6	0.5	0.6	4	8
Tributaries of Millers River	No. of Readings	20	30	15	20	30	15	14	30	15	20	30	15	5	30	15	20	20
	Range	12 80	15 165	20 150	37 60	31 48	32 66	9.3 13.2	6.2 11.9	5.6 8.4	5.1 6.1	4.8 6.4	5.6 6.9	0.4 1.0	0.4 2.0	1 2	4 56	8 54
	Average	39	55	98	47	40	48	11.6	9.5	6.9	5.5	5.5	6.2	0.6	0.8	1.6	30	29

Table 14-B. Summary of Physical Data

		Color Pt.-Co. Units			Specific Conductance Micromhos/cm			Dissolved Oxygen mg/l			pH			Turbidity Hach J.T.U.			Turbidity Spec. 20 J.f.U.	
Quarter		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
Ware River	No. of Readings	8	12	6	8	12	6	5	12	6	8	12	6	2	12	6	8	8
	Range	25 30	30 80	45 70	57 71	44 59	45 62	12.2 14.2	6.7 11.4	7.0 8.7	5.3 5.9	5.4 6.3	6.3 7.3	0.8 0.8	0.6 2.0	2 3	20 22	22 36
	Average	28	51	55	65	49	55	13.1	9.3	7.8	5.7	6.0	6.9	0.8	1.2	2.8	21	28
Connecticut River	No. of Readings	4	6	3	4	6	3	2	6	3	4	6	3	1	6	3	4	4
	Range	18 22	20 25	22 25	112 123	71 123	116 150	12.0 12.1	9.4 13.4	8.3 9.3	5.7 6.7	6.8 7.1	6.7 7.7	2.0 2.0	2.0 6.0	3.0 3.0	20 22	16 26
	Average	20	22	25	118	94	135	12.0	11.2	8.8	6.4	7.0	7.2	2.0	2.8	3.0	21	20
Millers River	No. of Readings	14	24	12	16	24	12	8	24	12	16	24	12	4	24	12	16	16
	Range	25 42	20 90	45 90	49 170	62 119	101 146	9.0 13.5	1.4 12.0	0.7 9.4	5.6 6.9	5.4 7.1	6.4 7.6	8 15	2.0 70	6 10	39 128	30 80
	Average	34	54	72	115	80	121	11.8	8.6	5.5	6.3	6.4	6.9	11	16	16	62	16

Figure 43. Color of Water at Riverine Stations

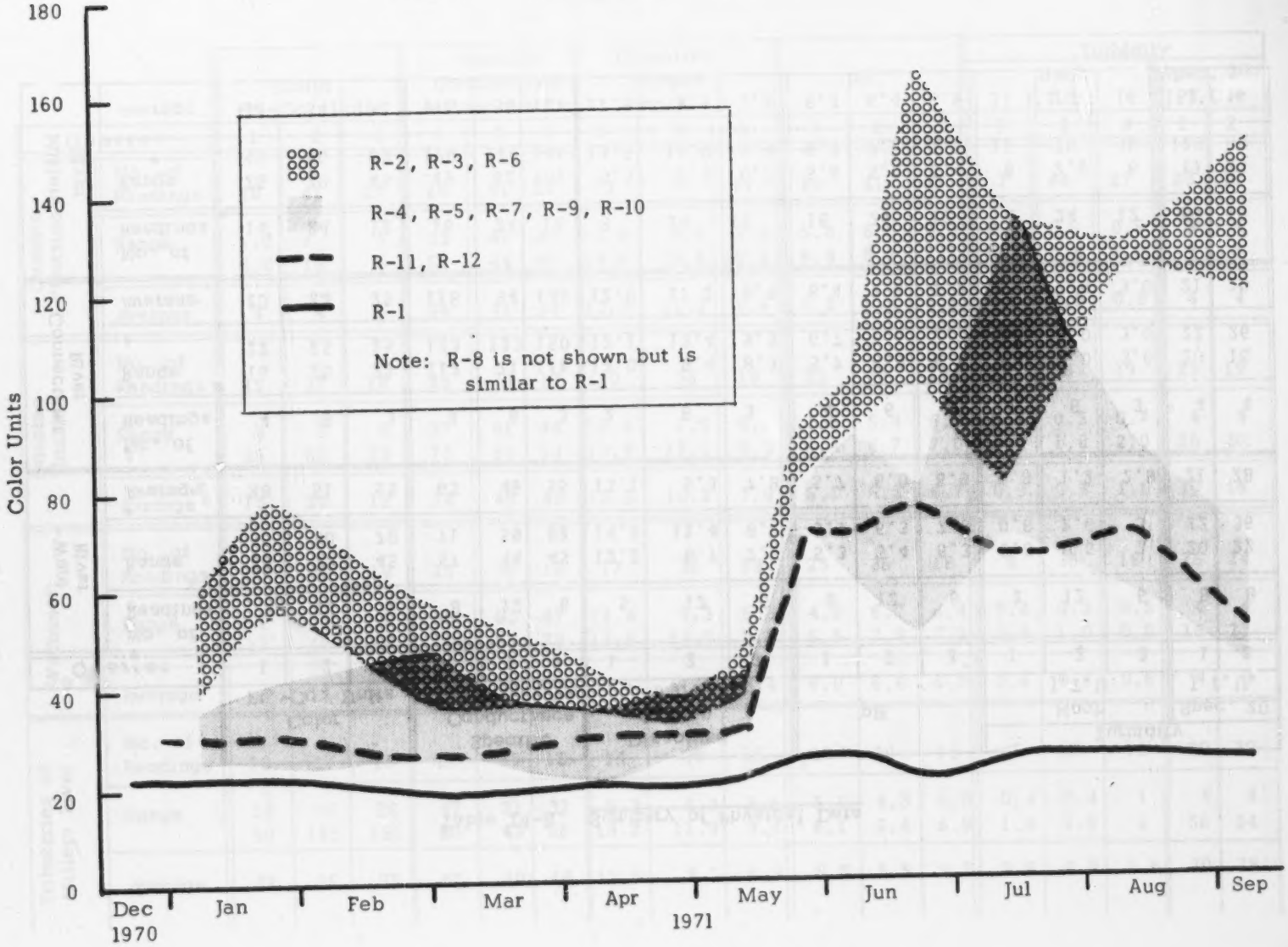
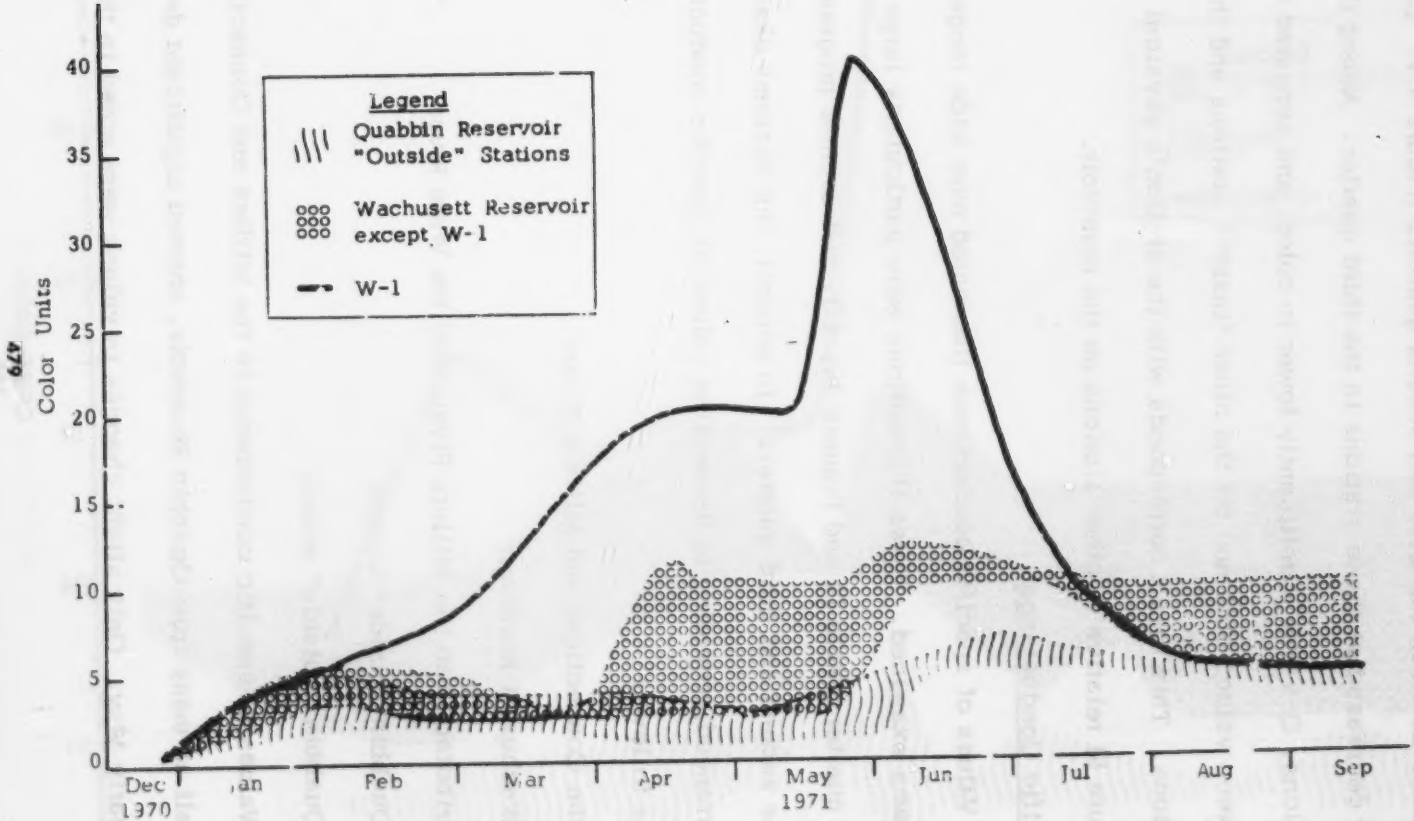


Figure 44. Color of Water at Quabbin "Outside" and Wachusett Reservoir Stations



diversion leaking into the sampling area through closed gates on the shaft. General increases in color were observed in Quabbin "inside" stations between the first and second quarters (Figure 45). Color generally decreased at these stations in the third quarter. Among these "inside" stations, Q-9 was significantly lower in color, and appeared intermediate between values obtained for the other "inside" stations and the "outside" stations. This result corresponds with the station's physical position (Figure 5) relative to other stations on the reservoir.

(2) Specific Conductance

Values of specific conductance fluctuated over wide ranges in each of the systems examined. These fluctuations were particularly large in the first quarter (Table 14 and Figures 46, 47), and became progressively smaller in the second and third quarters. In general, the systems examined can be arranged according to decreasing values of specific conductance (Table 14) as follows:

(a) the Connecticut and Millers Rivers

(b) Wachusett Reservoir

(c) tributaries to the Millers River, and the Ware River

(d) Quabbin "inside" waters

(e) Quabbin "outside" waters

Values of specific conductance in the Millers and Connecticut Rivers as well as many from Quabbin Reservoir, showed significant drops in April and early May. Only slight changes in values were noted in the tributary

Figure 45. Color of Water at Quabbin "Inside" Stations

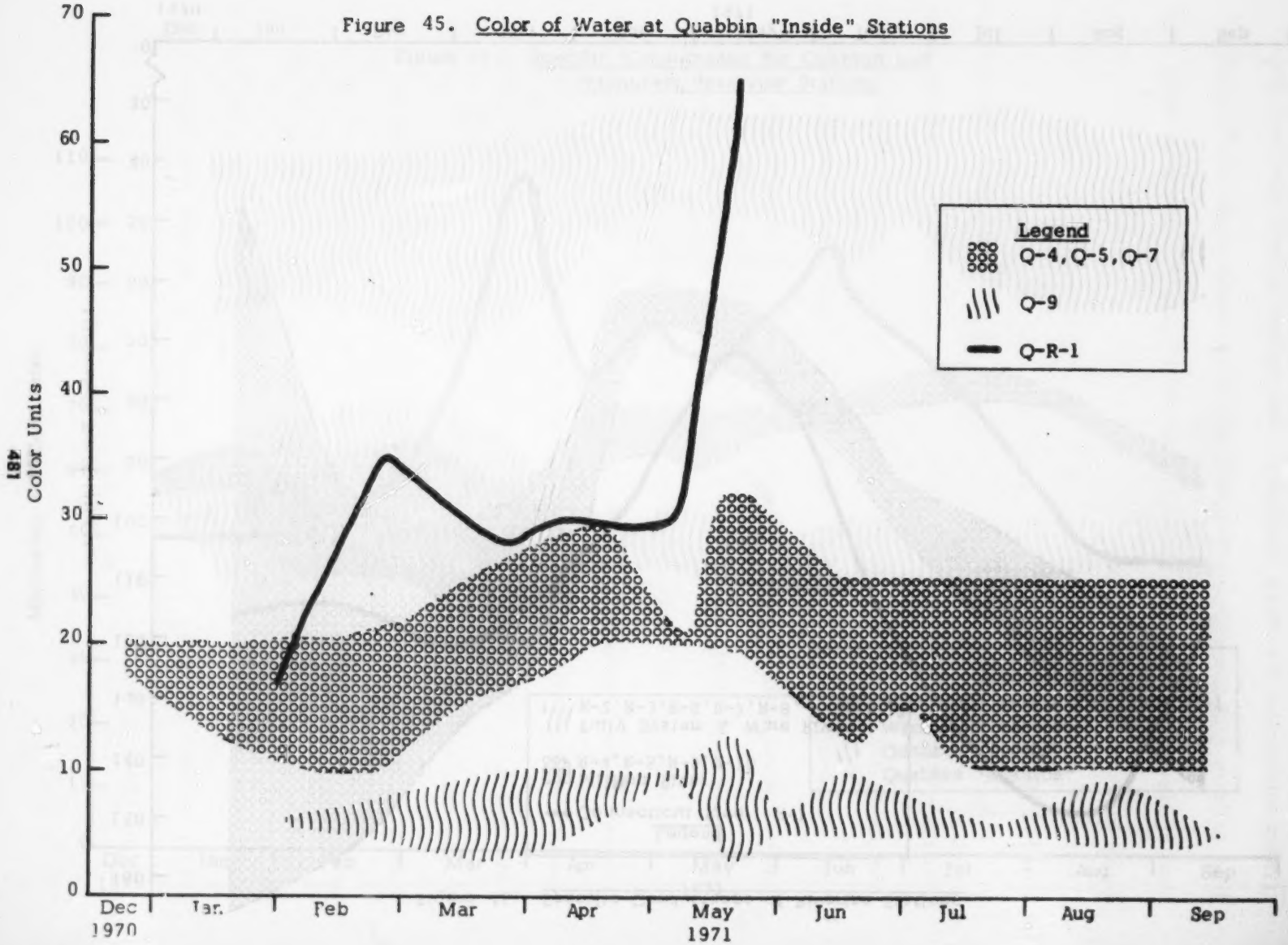


Figure 46. Specific Conductance of Riverine Stations

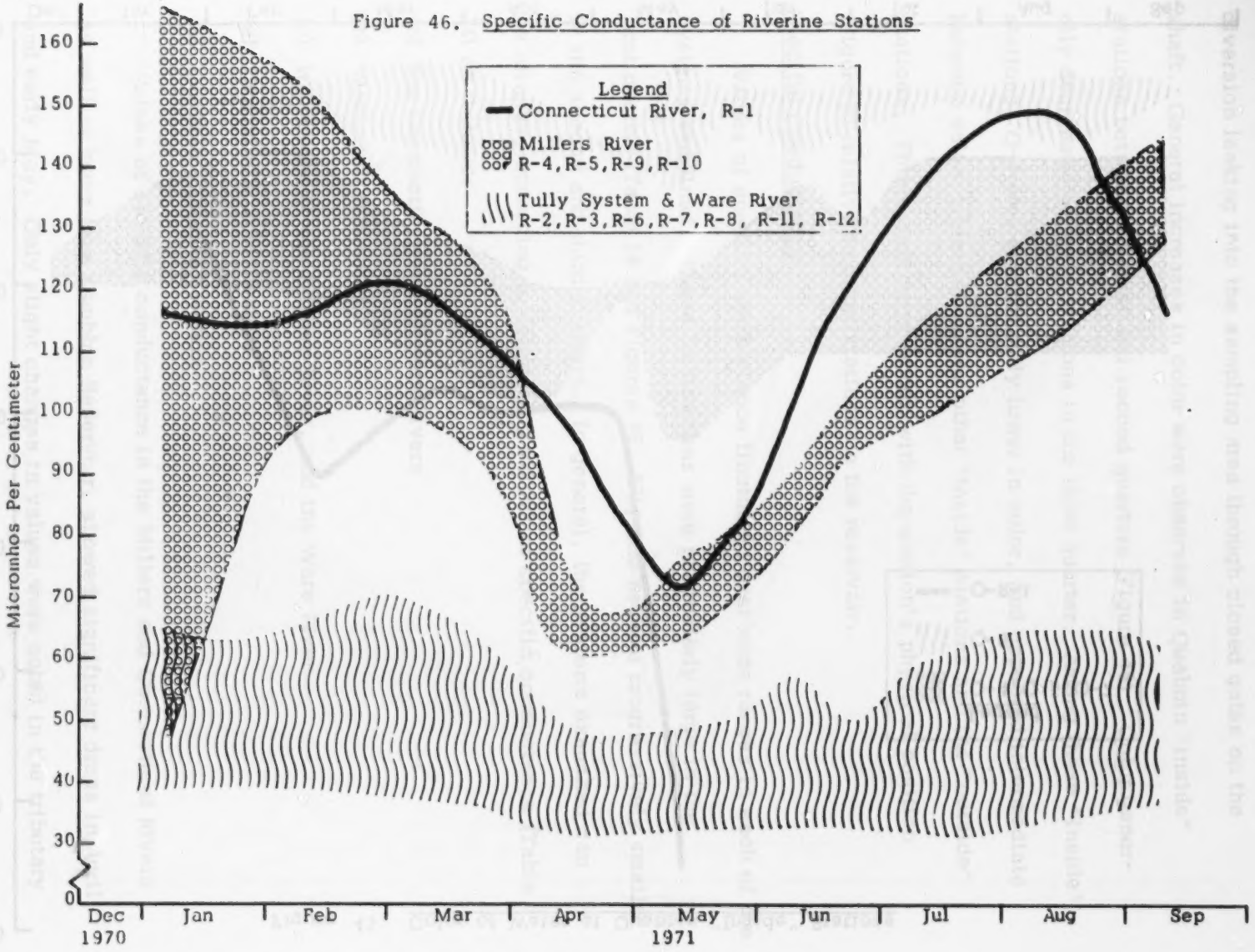
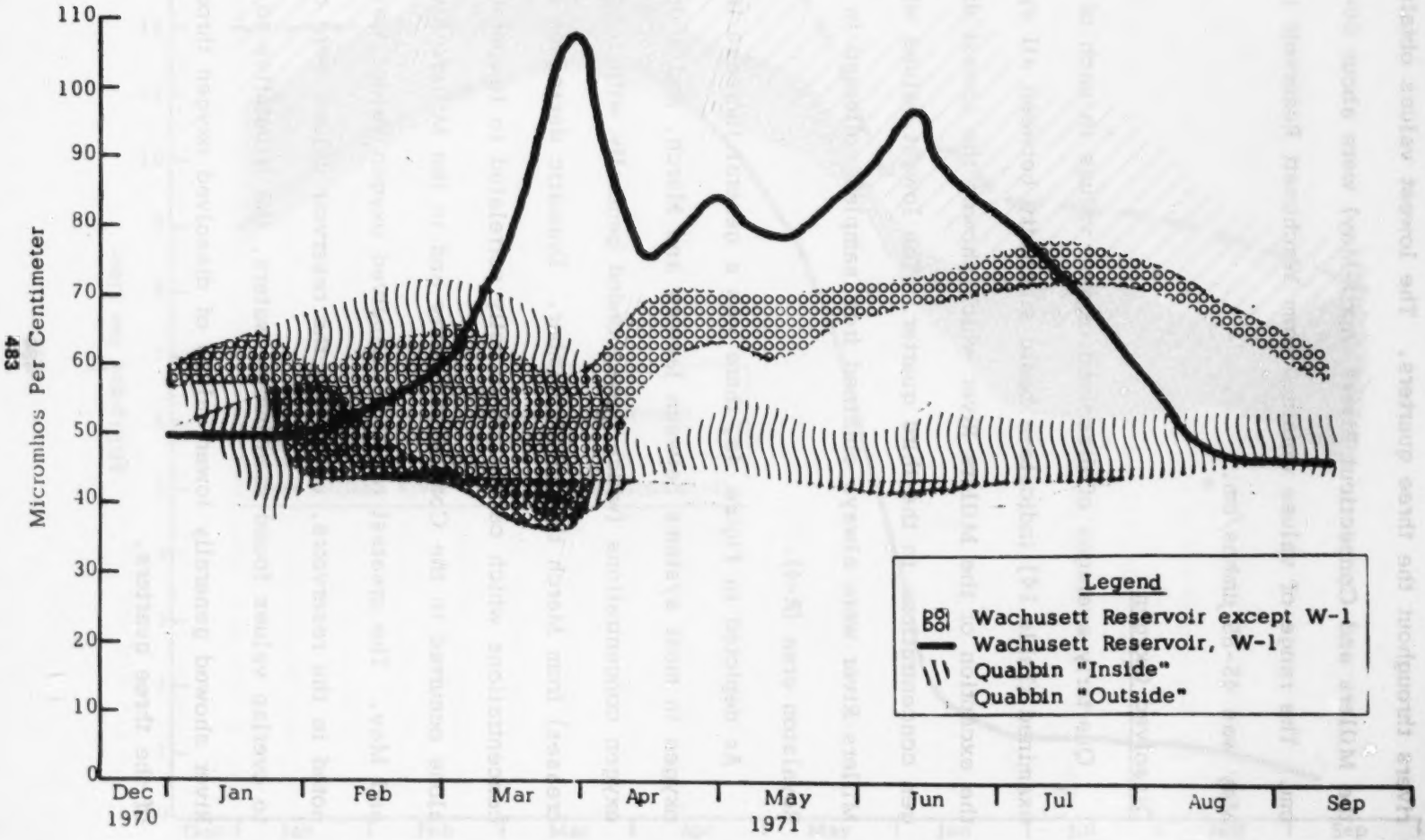


Figure 47. Specific Conductance for Quabbin and Wachusett Reservoir Stations



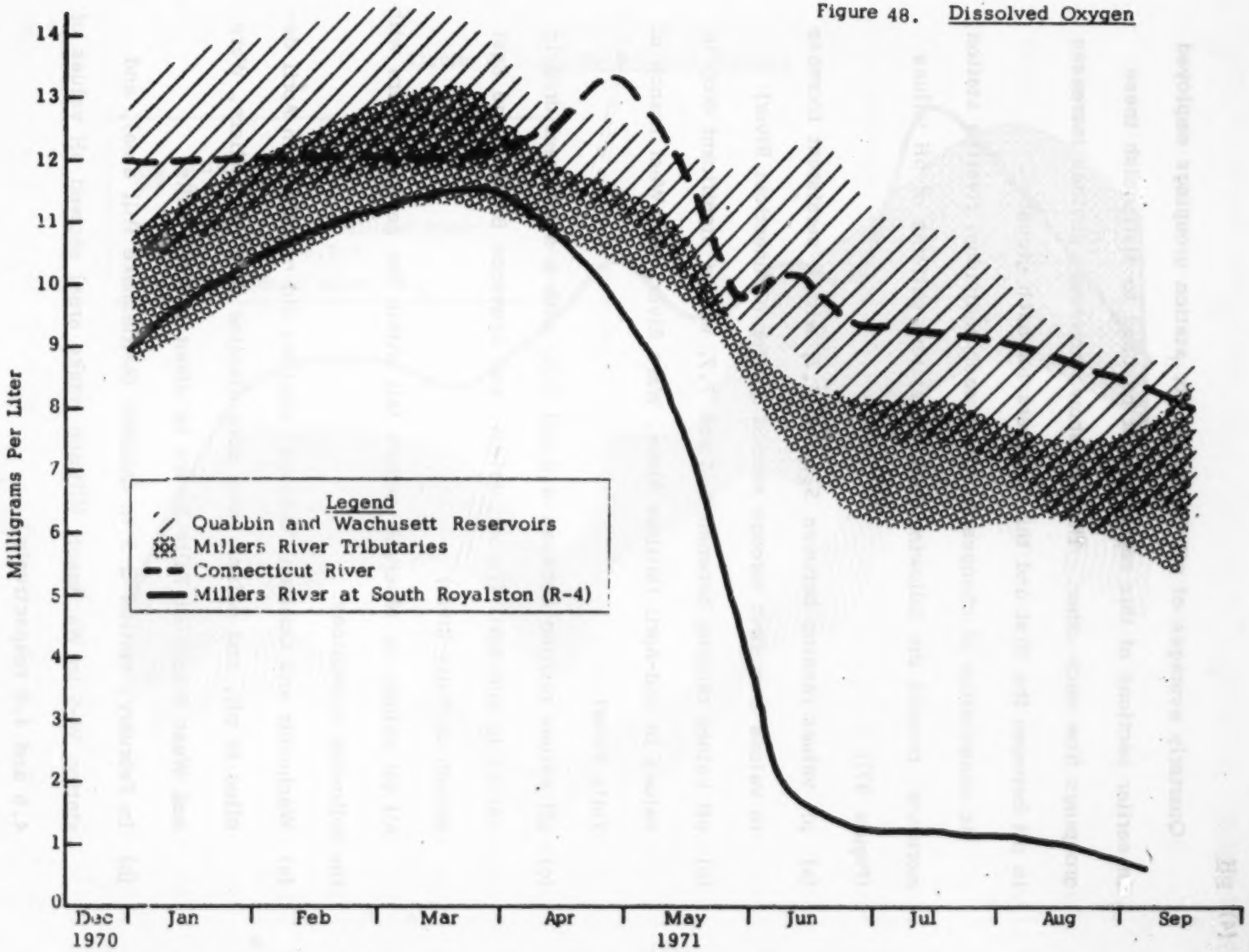
rivers throughout the three quarters. The lowest values obtained from the Millers and Connecticut Rivers (April-May) were about 60-70 μmhos/cm. The range of values obtained from Wachusett Reservoir in April and May was 45-85 μmhos/cm.

(3) Dissolved Oxygen

Quarterly averages of dissolved oxygen values in each of the systems examined (Table 14) indicate a basic similarity between all systems with the exception of the Millers River which showed the lowest dissolved oxygen concentrations in the third quarter. The lowest values within the Millers River were always obtained from samples collected in the South Royalston area (R-4).

As depicted in Figure 48, there was a general increase in dissolved oxygen in most systems between January and March, and a decrease in oxygen concentrations (which corresponded generally with temperature increases) from March through September. Dramatic decreases in oxygen concentrations which cannot be directly correlated to temperature change alone occurred in the Connecticut River and in the Millers River in April and May. The greatest range of dissolved oxygen values was consistently noted in the reservoirs, and while the reservoir values were often observed to overlap values found in tributary waters, the tributaries to the Millers River showed generally lower values of dissolved oxygen throughout most of the three quarters.

Figure 48. Dissolved Oxygen



(4) pH

Quarterly averages of pH (Table 14) for station groupings employed in earlier sections of this report cannot be used to distinguish these groupings from each other. They do show, however, obvious increases in pH between the first and third quarters for each grouping.

An examination of changes in pH at each individual riverine station, moreover, reveals the following three persistent patterns of pH values (Figure 47):

(a) pH values ranging between 5.7 and 7.7, with a persistent increase in values from first through second quarter (Connecticut River)

(b) pH values ranging between 5.3 and 7.7, with a significant drop in values in mid-April (Millers River, Ware River, and West Branch of Tully River)

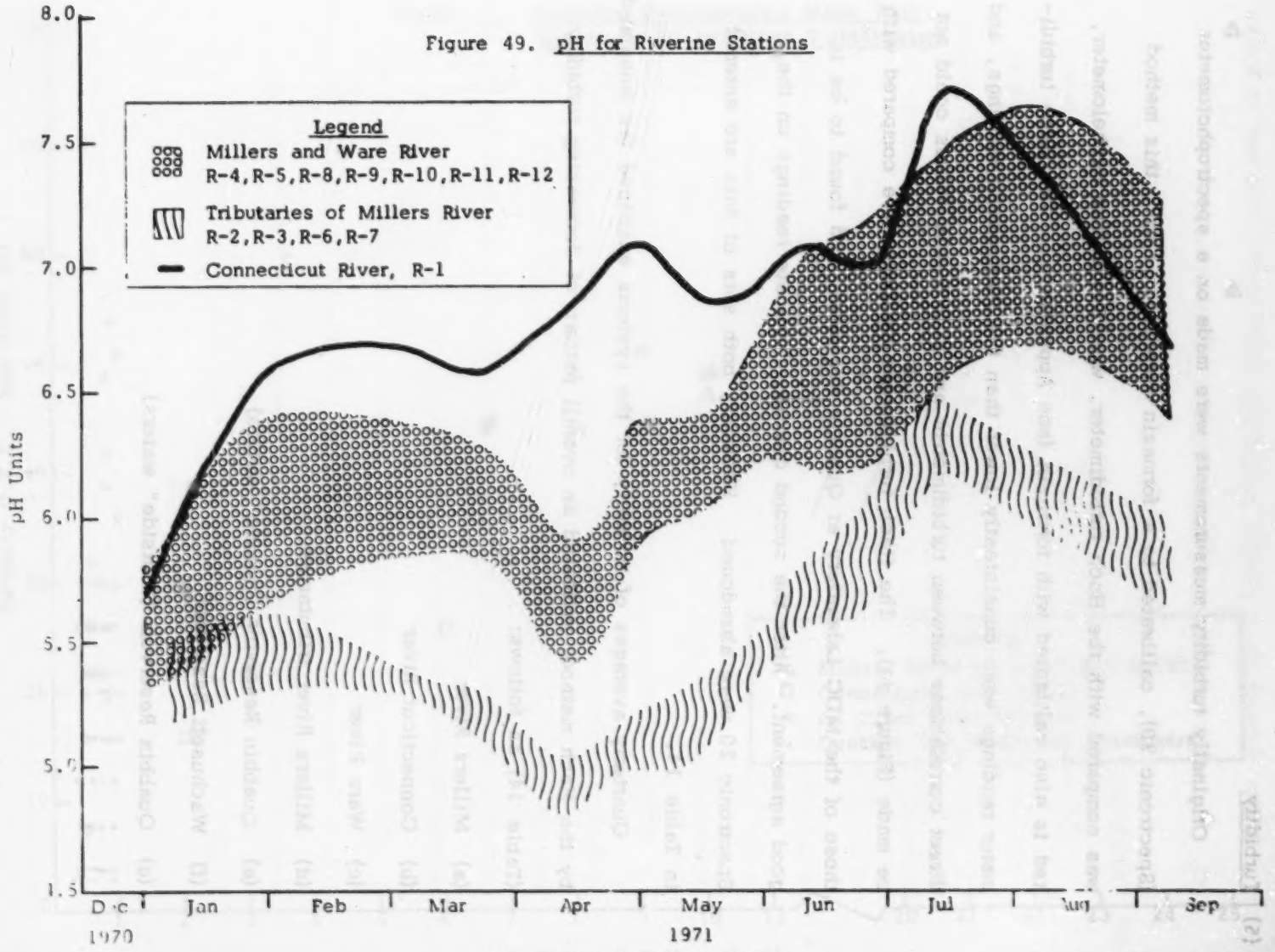
(c) pH values ranging between 4.8 and 6.6, with a significant drop in values in mid-April (Tarbel, Priest, and Lawrence Brooks, and East Branch of Tully River)

All pH values for reservoir waters fall within the second pattern with the following exceptions:

(a) Wachusett and Quabbin "outside" stations did not show an April decline in pH, and values were more alkaline than the Millers, Ware and West Branch of Tully Rivers by about 0.5 log units.

(b) In February, station Q-5 in Quabbin (Rattlesnake Hill area), and station W-5 in Wachusett (Clinton intake area) showed pH values of 4.6 and 4.8 respectively.

Figure 49. pH for Riverine Stations



(5) Turbidity

Originally turbidity measurements were made on a spectrophotometer (Spectronic 20), calibrated to a formazin standard. Later, this method was compared with the Hach turbidimeter, which is a true nephelometer, and is also calibrated with formazin (see Appendix 1). The Hach turbidimeter readings were consistently lower than the photometric readings, and direct correlations between turbidimetric and photometric values could not be made (Figure 50). The Hach turbidimeter readings were compared with those of the MDC Laboratory at Quabbin Reservoir, and found to be in good agreement. After the second quarter, duplicate readings on the Spectronic 20 were abandoned. However, both sets of data are entered in Table 14.

Quarterly averages of turbidity for the systems examined (as measured by the Hach method) indicated an overall pattern of decreasing turbidity (Table 14) as follows:

(a) Millers River

(b) Connecticut River

(c) Ware River

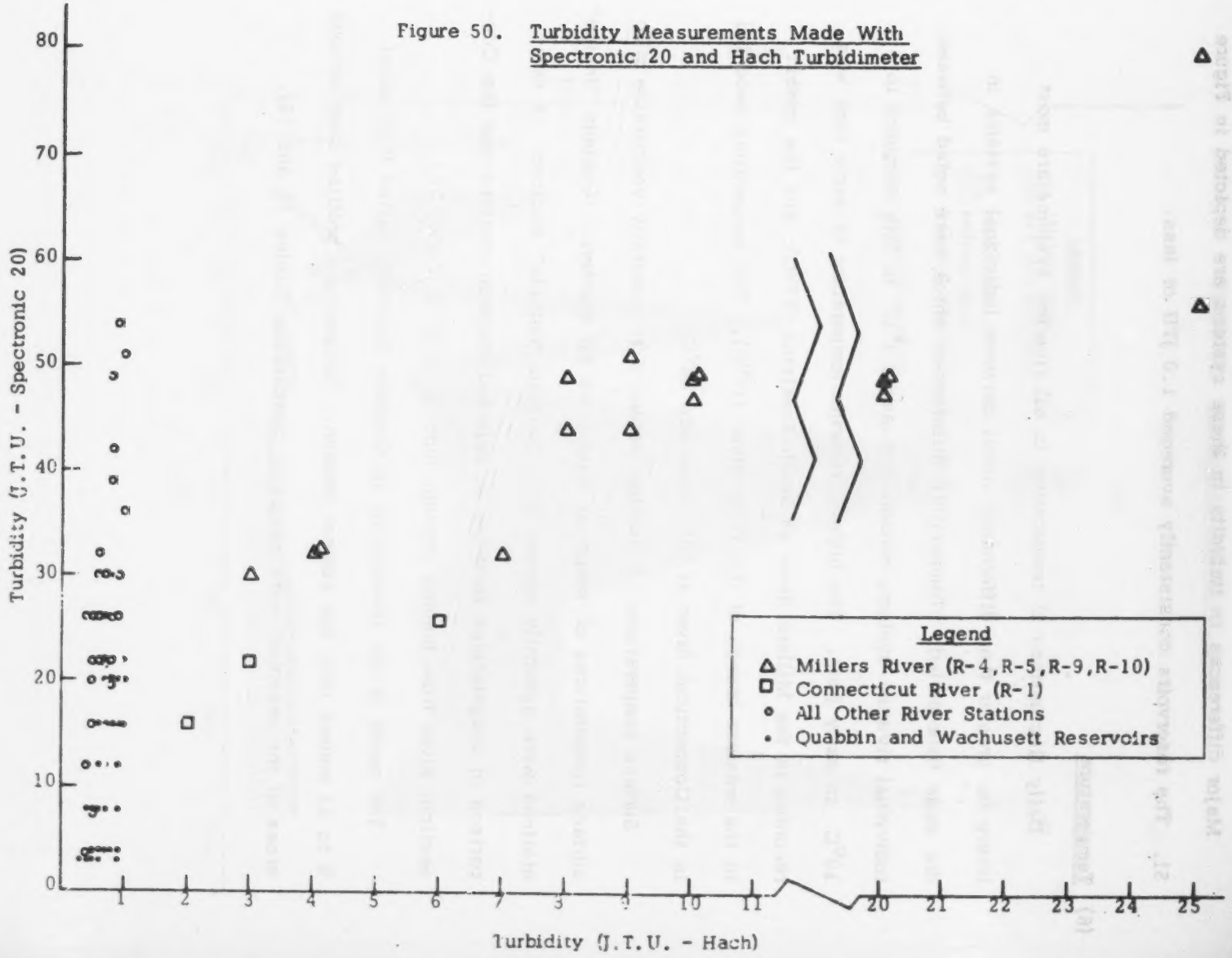
(d) Millers River tributaries

(e) Quabbin Reservoir ("inside" waters)

(f) Wachusett Reservoir

(g) Quabbin Reservoir ("outside" waters)

Figure 50. Turbidity Measurements Made With Spectronic 20 and Hach Turbidimeter



Major differences in turbidity in these systems are depicted in Figure 51. The reservoirs consistently averaged 1.0 JTU or less.

(6) Temperature

Daily fluctuations of temperature in all riverine systems are most likely far greater than differences noted between individual systems in the same time period. Temperature differences which were noted between individual riverine systems ranged from about 1°C in late February to 10°C in early June. The highest riverine temperature in early June was recorded in the Millers River at South Royalston (27°C), and the lowest in the western branch of the Tully River (17°C). The temperature recorded in the Connecticut River at this time was 20°C.

Surface temperatures of riverine waters were generally comparable with surface temperatures of reservoir waters for all quarters. Quabbin "inside" stations were generally warmer than Quabbin "outside" stations. A comparison of temperatures recorded at selected Quabbin stations and the Connecticut River from January through June is made in Figure 52.

The depth of the thermocline in Quabbin Reservoir varied from about 5 to 11 meters over the summer season. Temperature profiles from various areas of the reservoir were generally comparable (Tables 15 and 16).

Figure 51. Turbidity for Riverine Stations

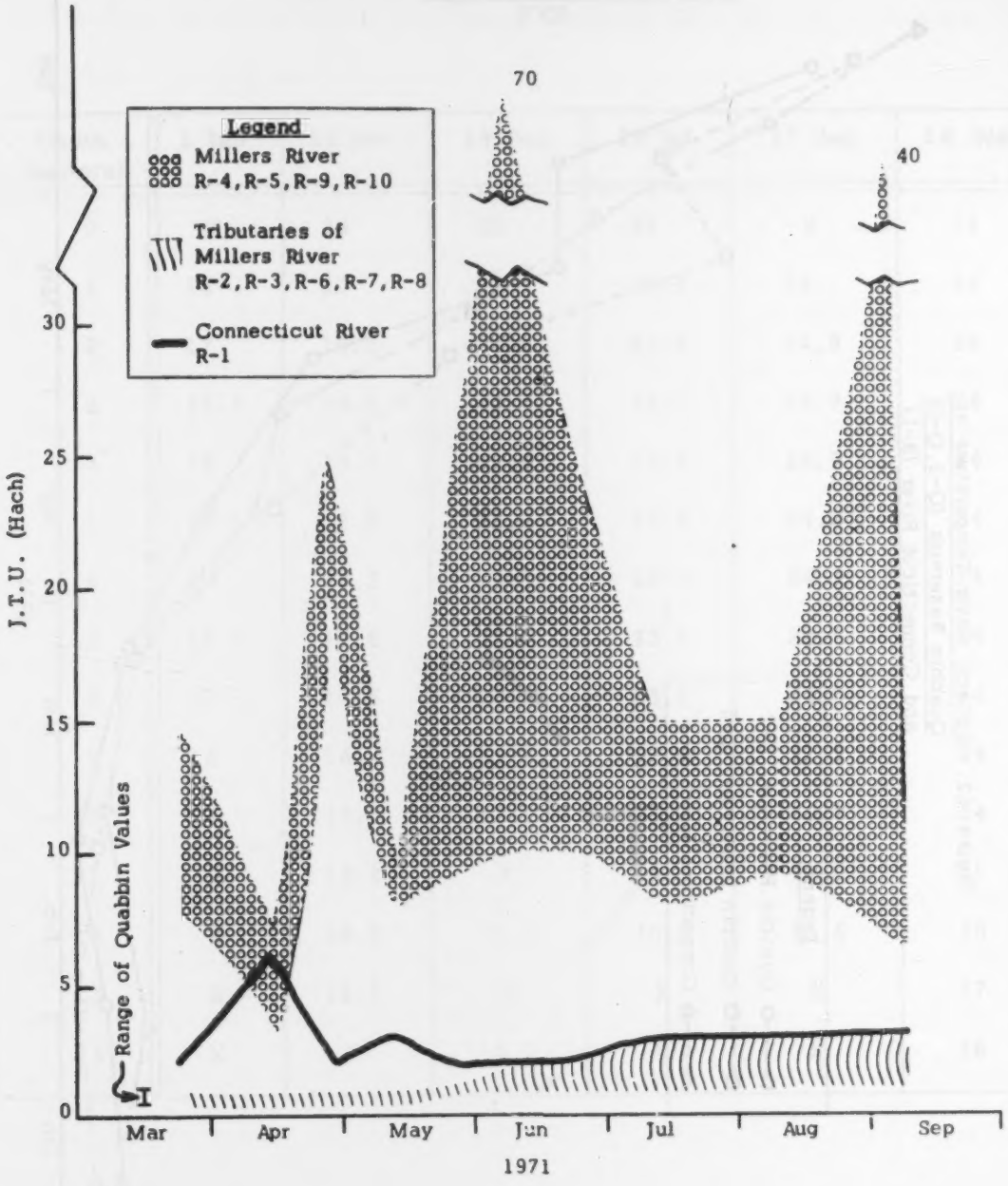


Figure 52. Surface Water Temperature at Quabbin Reservoir (Q-2, Q-5) and Connecticut River (R-1)

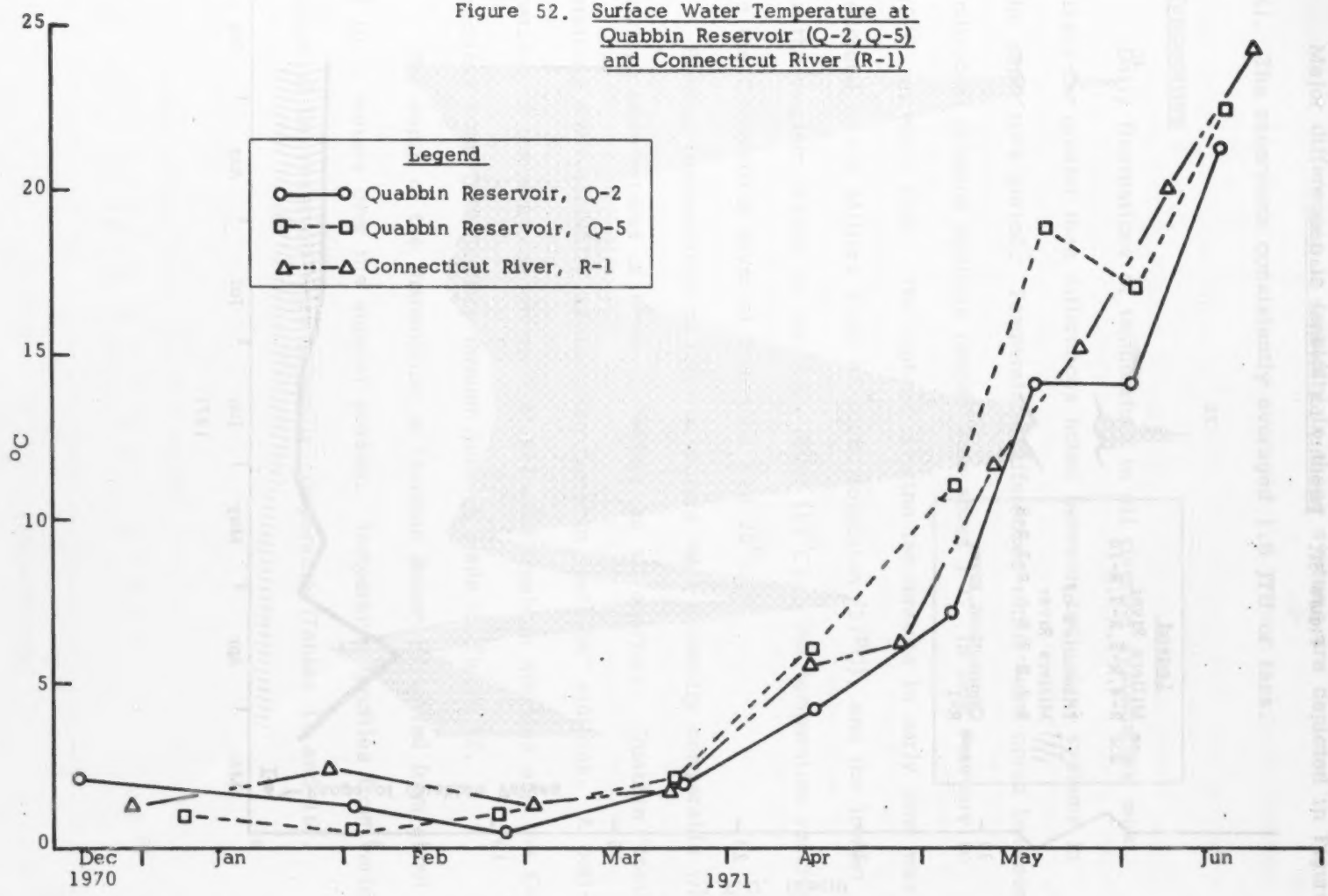


Table 15. Temperature Profiles at Quabbin Reservoir (Q-9) (°C)

Depth (meters)	1 Jun	15 Jun	29 Jun	20 Jul	17 Aug	14 Sep
0	X	20	23	24	X	24
1	15	20	23	23.9	25	24
2	17	19.8	22.9	23.9	24.9	24
3	16.5	19.6	22.9	23.7	24.9	24
4	16	19.4	22.9	23.5	24.9	24
5	13.5	19.0	22.9	23.3	24.8	24
6	13	18.2	22.5	23.3	24.7	24
7	12.5	17.8	22.0	23.1	24.5	24
8	12	15.2	20.2	23.1	24.0	24
9	12	14.2	19.1	23.0	22.2	24
10	12	14.0	17.1	22.1	18.9	24
11	X	13.2	X	18.5	17.0	21
12	X	13.0	14.3	16.2	15.5	18
13	X	12.5	X	X	X	17
14	X	X	14.1	X	X	16

Table 16. Temperature Profiles at Quabbin Reservoir (Q-2) (°C)

Depth (meters)	22 Dec	15 Apr	3 Jun	1 Jul	22 Jul	19 Aug	16 Sep
0	2	4.2	X	24.2	X	24.6	26.0
1	5	4.2	X	23.9	24.0	24.4	25.0
2	5	4.2	X	23.9	23.8	24.4	23.7
3	5	4.1	15	23.5	23.5	24.3	23.3
4	5	4.1	X	23.3	23.2	24.2	23.3
5	5	4.1	X	23.1	23.1	24.1	23.3
6	5	4.1	14.8	23.0	23.1	23.9	23.1
7	5	4.1	X	21.5	23.0	23.7	23.0
8	5	4.1	14.5	19.0	22.9	23.5	X
9	5	4.1	X	17.5	22.9	23.3	X
10	5	4.1	X	16.0	19.0	23.1	X
11	5	4.1	X	15.5	16.0	18.5	X
12	5	4.1	X	13.8	X	X	X
13	5	4.1	X	X	X	X	X
14	5	4.1	X	X	X	X	X
15	5	4.1	X	X	X	X	X

D. Pesticide Data

Twenty-seven reservoir and riverine stations were sampled and tested for pesticides. The breakdown on the stations is as follows:

Quabbin Reservoir	15
Wachusett Reservoir	6
Rivers (Stations 1,2,3,5,7,8)	6

The stations were sampled during the winter (Jan.-Feb.), the spring (May) and the summer (August). One station (Q-R-1) was not sampled in August because of no flow from the Ware River Diversion. Fourth quarter samples were collected in November; the results are presented in the subsequent supplementary report, (Appendix 6, Fourth Quarter Data).

Table 17 lists the pesticides and the detection sensitivities required for the project. In no instance did the water samples contain insecticides or herbicides above the required detection sensitivities. For example, whenever a trace amount of any chlorinated hydrocarbon pesticide was detected, the levels were reported as less than 10^{-4} ppm. Trace amounts of the chlorinated insecticides and the organic phosphates/carbamates were seen in both the winter and summer samples. Nothing was detected in the second quarter (May) samples. Absolute identification was not required for trace amounts. No attempt was made to positively identify PCBs in any of the waters. They may have been present, but the levels were so low that no positive identification of any peaks possibly attributable to these compounds was carried out. Table 18 summarizes the presence of trace amounts of various groups of compounds. No herbicides were detected.

Table 17. List of Pesticides and Required Sensitivity for Detection Techniques

Compound	Sensitivity in ppm
Aldrin	±0.0001
Chlordane	±0.0001
DDT	±0.0001
Dieldrin	±0.0001
Endrin	±0.0001
Heptachlor	±0.001
Heptachlor epoxide	±0.001
Lindane	±0.0001
Methoxychlor	±0.0001
Organic Phosphates and Carbamates	±0.01
Toxaphene	±0.0001
2,4-D	±0.01
2,4,5-T	±0.01
2,4,5-TP	±0.01
Phenols	--

As seen in Table 17 the project required the detection of phenolic compounds. Because of confusion on sensitivity requirements, no analyses were possible on the winter samples. Subsequent water samples were analyzed as described in the methods section of this report. No traces of phenols were detected in the May samples. Trace amounts (0.01 to <0.01 ppm) of phenolic substances were detected in 4 river samples collected in August. Specific locations are shown in Table 18.

In conclusion, the results show only trace amounts of pesticides where present, no amounts exceeded the sensitivity requirements, the spring (May) samples were free of pesticides, and traces of phenolic compounds were seen in the summer river waters.

Table 18. Summary for Detection of Trace Amounts of Pesticides and Phenols

Stations omitted from the Table showed no traces of any compounds.

Station	First Quarter	Third Quarter
Q-2-S	OP/C	
Q-2-10		A
Q-3-Tap		OP/C
Q-7-S	OP/C	
Q-8-S	OP/C	
Q-9-S	A,L	
Q-9-10	OP/C	
Q-R-1	OP/C	
W-2-S	OP/C	
W-5-S	A	
W-5-10	A,L	
R-1	L	
R-2		Ph
R-3	A,D,L	Ph
R-5	A,H,HE,L	L, OP/C
R-7	A,D,H	Ph
R-8	A	Ph

Compound Codes: OP/C = Organic Phosphates/Carbamates, A = Aldrin, D = Dieldrin, H = Heptachlor, HE = Heptachlor Epoxide, L = Lindane, Ph = Phenols

E. Radioactivity.

Originally it was agreed that the sponsoring agencies were to provide NER with the appropriate data on radioactivity for all systems under study. Later it was decided that NER would collect the water and deliver it to the Lawrence Experiment Station for analyses at their Radiological Health Lab. Over the period July 15-22 a total of 32 samples were collected. They were distributed as follows: rivers - 12; Quabbin Reservoir - 14; Wachusett Reservoir - 6. Station Q-R-1 at Quabbin was omitted because it was dry; the Ware River was not being diverted.

The results of analyses showed all samples to have gross beta activity below 10 $\mu\mu$c/liter. Of the river stations, R-2, R-4, R-6 and R-7 showed the highest values (6 and 7 $\mu\mu$c/liter). No gross alpha activity was detected in any water samples. Because of the low beta activity and undetectable alpha activity, no tests were performed for ^{226}Ra and ^{90}Sr. The policy of the Lawrence Experiment Station is not to test for ^{226}Ra if the gross alpha activity is under 1 $\mu\mu$c/liter, nor for ^{90}Sr if the gross beta activity is less than 10 $\mu\mu$c/liter.

Additional water samples were collected in November. The results of those analyses are reported in the subsequent supplement, (Appendix 6).

6. OTHER INFORMATION

A. Hydrodynamic Studies

This section is a summary of the hydrodynamic studies of the Quabbin Reservoir carried out under subcontract by the Alden Research Laboratories (Hecker and Yale, 1971).

Because of the three-dimensional geometry of the reservoir and the complex, periodic nature of the diversions, analytic techniques could not be applied with confidence until some understanding of the basic reservoir hydrodynamics was available. To this end, a small-scale hydraulic model of Quabbin Reservoir was constructed and tested. The horizontal scale was 1:4000, while the vertical conversion ratio was 1:200. Appropriate Froude model similitude and scaling criteria were employed. Flow patterns in a model of this type are due mainly to inertia and gravity forces. Isothermal conditions (i.e. no stratification) were assumed, and no attempt was made to account for surface shearing forces due to winds. Finally, the density of the inflow water was the same as that of the reservoir water. Dye tracers were used to study flow patterns. Photographs were taken at periodic intervals, and the running time in hours was converted to the equivalent time in days. Thus basic reservoir dynamics including retention times and circulation patterns over a period of days could be studied on the model.

The study is presented in three sections. The first is an attempt to study the flows between the west branch and the main reservoir. The second section includes calculations of dilutions and retention times. Finally the third section

is a discussion of the flow patterns.

(1) Flow Between West Branch and Main Reservoir

Stage-volume curves for both the west branch and the entire reservoir were prepared. For known inflows or withdrawals over a given period, the change in volume and thus the change in surface elevation of the entire reservoir can be determined. Assuming a horizontal water surface, volume changes in the west branch can be determined. Therefore, for the same time period, the average flow into or from the west branch can be calculated.

Two cases producing inflows to the west branch from the main reservoir, and one case producing outflow from the west branch into the main reservoir were considered. Using the cross-sectional area of the narrows connecting the west branch and the main reservoir, the calculations indicate that the velocities associated with the net flows into or from the west branch would be negligible and not measurable with standard current meter techniques. While the stage-volume curves of the MDC differed,[1] the results show that an exchange of water between the west branch and the main reservoir should be expected irrespective of those differences. This conclusion was verified by the flow pattern studies described below.

(2) Dilutions and Retention Times

Several cases involving various operating conditions were considered

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[1]The model was constructed with templates prepared from U. S. Coast and Geodetic and Borden Surveys taken in 1885 and 1887. The M.D.C. conducted field surveys in the 1930's.

for calculating dilution ratios. Assumptions included an initial reservoir level of 508 feet and diversion and Swift River inflows of 70 days. The results are shown below:

Case	Inflows	Inflow Duration (days)	Dilutions
I	Ware River Diversion & Swift River branches	70	5.2
II	Connecticut River Diversion and Swift River branches	70	2.1
III	Connecticut and Ware River Diversions and Swift River branches	70	1.5

The dilutions represent the amount that the input volume would be diluted by the volume of the reservoir in the main and east branches north of Shaft 12. If the reservoir volumes of the east and main branches to Winsor Dam are considered, the dilution ratio for Case III is 3.5. Slightly higher values would be obtained from the MDC stage-volume data.

Retention times were computed using the model topographical and stage-volume data. Calculations were based on velocities of total inflows at various reservoir cross-sections, and on the inflows displacing all reservoir volume north of Shaft 12. The conditions shown in Table 19 for Test 3 were used for the calculations. Assuming all ambient reservoir volume northeast of the baffle dams and the "gap" between Mt. Zion and

Mt. L (Figure 5) were displaced by the inflow, it would take approximately 35 days for the Connecticut, Ware and Swift River flows to reach the gap. An additional 50 days would be required to displace the reservoir volume from the gap to Shaft 12, or a total "travel time" of 85 days. Slightly shorter travel times resulted from calculations based on cross-sectional flow velocities southward from the gap. Travel times would presumably be slightly longer when based on the somewhat greater volumes of the MDC stage-volume data.

(3) Flow Patterns

Three different test series to study flow patterns were run on the model. The test conditions for the three test series are shown in Table 19. Appropriate dyes were used for the various inflows. The advance of the dye "fronts" was used to gain insight into the dynamics of the flow patterns. The results of these tests are summarized in Table 20. Note that the reservoir level for Tests I and II was 530', whereas it was 508' for Test III. Of interest is the lack of a direct flow path toward Shaft 12. To confirm this, concentrated dye was introduced at four locations in the intake vicinity after 260 days of elapsed time in Test II. The results show random fluid motion in the southeastern portion of the middle branch, and indicate that the withdrawn flow is a mixture of water from that area.

(4) Tully Diversion Studies

Following these studies, the Army Corps of Engineers requested that

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Table 19. Summary of Inflow and Outflow Conditions for the Studies of Flow Patterns

			Months 1	2	3	4	5	6	7	8	9	10	11	12
TEST I														
Reservoir El. 530 ft.														
INFLOWS:	Ware River	250 cfs	→	→	→	→	→	→	→	→	→	→	→	→
OUTFLOWS:	Winsor Dam	50 cfs	→	→	→	→	→	→	→	→	→	→	→	→
TEST II														
Reservoir El. 530 ft.														
INFLOWS:	Ware River	250 cfs	→	→										
	Connecticut River	600 cfs	→	→										
OUTFLOWS:	Winsor Dam	50 cfs	→	→	→	→	→	→	→	→	→	→	→	→
	Shaft 12	450 cfs			→	→	→	→	→	→	→	→	→	→
TEST III														
Reservoir El. 508 ft.														
INFLOWS:	East Br. Swift River	100 cfs	→	→	→									
	Middle Br. Swift River	30 cfs	→	→	→									
	West Br. Swift River	50 cfs	→	→	→									
	Ware River	250 cfs	→	→	→									
	Connecticut River	600 cfs	→	→	→									
OUTFLOWS:	Winsor Dam	50 cfs	→	→	→	→	→	→	→	→	→	→	→	→
	Shaft 12	450 cfs			→	→	→	→	→	→	→	→	→	→
TEST IV														
Reservoir El. 508 ft.														
INFLOWS:	East Br. Swift River	100 cfs	→	→	→									
	Middle Br. Swift River	30 cfs	→	→	→									
	West Br. Swift River	50 cfs	→	→	→									
	Ware River	250 cfs	→	→	→									
	Connecticut River	600 cfs	→	→	→									
	Tully River	350 cfs	→	→	→									
OUTFLOWS:	Winsor Dam	50 cfs	→	→	→	→	→	→	→	→	→	→	→	→
	Shaft 12	450 cfs			→	→	→	→	→	→	→	→	→	→

Table 20. Summary of Model Flow Pattern Studies

Test Series	Position of Dye Front	Days Required to Reach Position	Comments
I	Southeast corner of Mt. Zion	35	
	Slight additional advance	50	
	Narrow section east of Mt. Zion	110	
	Gap north of Mt. Zion	230	Some diffusion into middle branch.
II	Conn. River water in northern portion of middle branch	50	
	Ware River water southeast side of Mt. Zion	60	
	Conn. River water through gap north of Mt. Zion	additional time beyond 50	Water follows original Swift River bed.
	Conn. River water southward along Swift River bed. Ware River water at narrow section east of Mt. Zion.	100	40 days after diversions stopped and withdrawal from Shaft 12 begun.
	Conn. River water mixed with southern portion of west branch.	200	Diffusion of both waters with water of main reservoir.

Table 20. Continued

Test Series	Position of Dye Front	Days Required to Reach Position	Comments
III	Conn. River and Ware River waters join at gap.	30	Begin to flow into middle branch.
	Beyond cut into middle branch.	55	
	Additional southward movement in middle branch.	70	Extensive mixing with middle branch. After withdrawal from Shaft 12 begun no evidence of established flow to Shaft 12.
		70 + 7 months	Extensive mixing of diverted waters with middle branch and southern part of west branch.
IV	All 3 Diversions mixed and at gap.	25	
	Dye well advanced into upper portion of middle branch.	65	Mixing continues
		70	Complete mixing in northern portion of middle branch. (Diversions stopped at 70 days; Shaft 12 flow started)
	Mixed flows at position opposite Shaft 12.	85	No direct flow path to Shaft 12.
	West Branch	275	Extensive mixing.

additional studies be conducted to include the proposed diversion flow from the Tully River System.

The test conditions for the model studies including the Tully System are shown in Table 19 under Test IV. The results are summarized in Table 20. In general, the results are similar to those with Test III, including the flow dynamics, travel time, and lack of direct flow to Shaft 12.

Calculations of flow times with the Tully Diversion results in a figure of 60 days, as opposed to 85 days for the model studies. This figure is less than the 85 days calculated for Test III, and is based upon the additional inflow from the Tully Diversion. The difference in travel time resulting from calculations as opposed to model tests is believed to be due to the difficulty in defining the exact position of the diffused dye front on the model. Calculations are believed to be more consistent and more indicative of trends than the model tests. Nevertheless all values, whether from computations or test runs fall within a relatively narrow range. Consequently, a retention time of 60 to 90 days for Connecticut River water is a reasonable range to consider for this study.

Finally, dilution ratios for the case of all three diversions were computed based on inflow volume relative to volume in the appropriate portion of the model reservoir. Swift River inflows from the east and middle branches during the 70 days of diversion were included to obtain a total ambient volume. The total diversion volume was then divided into the

ambient volume north of Shaft 12 to obtain a dilution ratio of 1:1. If the reservoir volume in the entire east and middle branches to Winsor Dam is considered, the dilution ratio is 2.5:1. See page 127 for dilution ratios of Cases I, II and III.

Dilution ratios and retention times would be slightly greater if the greater volume of the MDC stage-volume data were used. Thus a dynamic range of ratios is possible depending upon reservoir volume. We wish to stress that travel times as reported in this study are only approximate values. Also, dilutions are based on assumptions of complete mixing. Stratification and wind phenomena under field conditions may result in less dilution and reduction in retention times for waters of riverine origin. This must be borne in mind when one reads Sections 7 - 10 of this report.

It is important to note that no basic differences in hydrodynamics were noted for the differences in elevation used in the tests. Flow of diversion input waters followed the same course in the reservoir, essentially along the original riverbed. We assume the model will show similar flow patterns for even lower elevations (e.g. 490 feet). However, the lower volumes will result in lesser dilution capacity for riverine waters.

B. Fisheries Information

Most of the information of this section came from Mr. Colton H. Bridges and his research staff of the Massachusetts Division of Fisheries and Game. The information came from both written reports and personal communications.

Sports fisheries in Quabbin Reservoir has its main attraction in a good salmonid (Salmonidae) fisheries program. Lake trout became well established in Quabbin Reservoir in the 1950s (Mullan, 1958). Smelt were also introduced, thus providing a forage for the lakers that reached piscivorous size. The smelt population grew so rapidly that the MDC experienced problems in its water supply and distribution system. Eventually control measures were instituted and the smelt population was reduced. This also had an impact on the lake trout and consequently the lake trout population was also reduced. In recent years attempts to restock lake trout and smelt have been carried out. These now appear to be successful, and there is concern within the Massachusetts Division of Fisheries and Game to maintain a proper ecological balance and viable fisheries program in the reservoir.

A checklist of species in Quabbin supplied by the Division of Fisheries and Game indicates 26 species. These include both warm water and cold water species. It is important to stress, however, that if the salmonid population decreases, the number of angler trips also declines. This is true even if the warm water population of fishes increases. Therefore, the maintenance of the water quality required to support the salmonids is considered vital by the Division of Fisheries and Game. Creel census figures for the 1950s and

1960s indicate that other species, including bass, pickerel, perch, bullheads, and walleye pike are also taken from Quabbin (Quabbin Reservoir Investigations, Project No. F-6-R-12, Job. No. 1)

Several other points are important to the current project. A Connecticut River Anadromous Fish Restoration Program is currently underway. The states of Vermont, New Hampshire, Massachusetts and Connecticut are cooperating with federal agencies to restore runs of anadromous fish in the river. This will require the development of fish ascending facilities. When these are completed, many species including lampreys will get above the Turners Falls Dam. A second point of interest is that experience with the Muddy Run (Pennsylvania) pumped storage facility shows that fish from the river were found in the upper reservoir. Finally, experiences with Quabbin have shown that smelt introduced into Quabbin also got into Wachusett Reservoir.

Turning briefly to the rivers, the mainstem Millers cannot now sustain a good fishery. The Tully System has species which are similar to those found in Quabbin. These are stocked each year. The Connecticut River has several undesirable species as far as possible introduction to Quabbin in concerned. These include carp, eels, and lampreys.

Field operations during the present study did not include an investigation of fisheries. However, our benthic and zooplankton samples were examined for fish eggs and fish larvae. One fish embryo was seen in a Quabbin zooplankton sample, and at one river station (R-7) developing larvae were present in a benthic sample. This lack of fish eggs or larvae is not attributable to

the mesh size of the plankton nets, but rather is related to sample locations and volume of water concentrated. In the reservoirs our stations are located in deep water whereas most spawning occurs in shallower waters. Fish eggs in streams are generally buried or attached, and are too infrequent to be found in the volumes of water concentrated for plankton samples. The same is true with regard to the frequency of larvae. Special techniques which take into consideration actual nesting spots would have to be considered in order to increase the probability of detecting eggs and larvae in samples.

Pollution Abatement Plans

In response to a request for a time schedule for the abatement of pollution on the Millers River, Mr. Slagle (Chief of Implementation and Enforcement, Massachusetts Division of Water Pollution Control) stated that by the end of 1972 all planned treatment plants on the Millers River should be operational. He also stated that water quality goals specified for the various Millers River basin waters by the Division of Water Pollution Control will have been met by the same date. According to the Millers River Basin Classification Plan (Massachusetts Division of Water Pollution Control, River Basins Classifications, 1967), all Millers River and its tributary waters examined in the progress of this study are expected to be up to Class "B" standards when the abatement program is complete.* This same master plan also calls for the eventual upgrading to Class "B" of waters of the Connecticut River from the New Hampshire, Vermont, Massachusetts state line to the dam at Holyoke, Massachusetts. No timetable is specified in that report.

Class "B" waters are defined in Water Quality Standards (Massachusetts Division of Water Pollution Control, 1967) as waters "suitable for bathing and recreational purposes including water contact sports; acceptable for public water supply with appropriate treatment; suitable for agricultural, and certain industrial cooling process uses; excellent fish and wildlife habitat; excellent aesthetic value". The water quality criteria upon which this classification is based are as follows:

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*Recent information indicates that it is unlikely that the proposed timetable for completion of the abatement program will be met. (Personal Communication, April 5, 1972, Mr. Everett Maynard, U S. Army Corps of Engineers).

Item	Water Quality Criteria
(1) Dissolved oxygen	Not less than 75% of saturation during at least 16 hours of any 24-hour period and not less than 5 mg/l at any time.
(2) Sludge deposits-solid refuse-floating solids-oils-grease-scum	None allowable.
(3) Color and turbidity	None in such concentrations that would impair any usages specifically assigned to this class.
(4) Coliform bacteria per 100 ml	Not to exceed an average value of 1000 during any monthly sampling period nor 2400 in more than 20% of samples examined during such period.
(5) Taste and odor	None in such concentrations that would impair any usages specifically assigned to this class and none that would cause taste and odor in edible fish.
(6) pH	6.5 - 8.0
(7) Allowable temperature increase	None except where the increase will not exceed the recommended limit on the most sensitive receiving water use and in no case exceed 83° F. in warm water fisheries, and 68° F. in cold water fisheries, or in any case raise the normal temperature of the receiving water more than 4° F.
(8) Chemical constituents	None in concentrations or combinations which would be harmful or offensive to human, or harmful to animal or aquatic life or any water use specifically assigned to this class.
(9) Radioactivity	None in concentrations or combinations which would be harmful to human, animal, or aquatic life for the appropriate

Item	Water Quality Criteria
	water use. None in such concentrations which would result in radio-nuclide concentrations in aquatic life which exceed the recommended limits for consumption by humans.
(10) Total phosphate	Not to exceed an average of 0,05 mg/l as P during any monthly sampling period.
(11) Ammonia	Not to exceed an average of 0.5 mg/l as N during any monthly sampling period.
(12) Phenols	Shall not exceed 0.001 mg/l at any time.

7. GENERAL DISCUSSION OF AVAILABLE DATA

A. Comparison of NER and Other Data, Connecticut River

In the progress of this study NER has reviewed a number of sources of water quality data which were available from public and private agencies (see Appendix 5). Any comparison of these data, however, must be qualified by the particular differences in time and place of collection of water samples which vary from study to study. Tables 1 and 2, for example, show values for parameters analyzed by NER and the MDC[1] using water samples collected from the Connecticut River during freshet flow. Water samples analyzed by the MDC were collected about 6 miles upstream from where samples were collected for analysis by NER, and were usually taken on different days and at different times of the day. The discrepancies noted in these data cannot therefore easily be attributed to any particular cause, and most likely reflect a complex set of factors. Similarly, no specific agreement of values can be used as definite proof of validity of these numbers.

Comparisons of all these data, however, are extremely useful in the definition of general water quality trends and patterns. They are necessary for setting individual data in perspective. Indeed, such comparisons can very well serve to define future research needs. For example, included in the report of water quality analyses which is abstracted into Tables 1 and 2 was the report of a

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1. Data provided by Leslie Campbell of the Quabbin Laboratory, MDC, November 4, 1971.

Table 21. Comparisons of Results of Water Analyses of Connecticut River - NER and MDC (April, 1971)

	NER Apr 12	MDC Apr 14	MDC Apr 15	MDC Apr 21	MDC Apr 22	NER Apr 28	MDC Apr 28
Dissolved Oxygen	12.5	12.8	13.7	12.8	12.6	13.4	13.0
Turbidity	6	16	15	12	18	2	6
Color	20	35	28	28	28	20	25
Hardness	22.8	30	32	30	X	28.9	28
pH	6.8	7.2	7.4	7.2	7.2	7.1	7.1
Iron	0.4	1.1	1.0	0.7	X	0.1	0.1
Manganese	0.04	X	0.00	0.00	X	0.00	X
Orthophosphorus	0.01	X	0.10	X	0.15	0.00	X
Nitrate Nitrogen	0.24	0.38	X	0.06	X	1.9	0.20
Nitrite Nitrogen	0.006	0.005	X	X	0.002	0.003	X
NH_3 Nitrogen	0.58	X	0.12	X	0.17	0.32	X
Specific Conductance	101	X	106	102	95	81	102
Fecal Coliforms per 100 ml.	300	300	410	520	600	X	450
Total Coliforms per 100 ml.	500	340	2900	2200	3000	X	5000

Table 22. Comparisons of Results of Water Analyses of Connecticut River - NER and MDC (May, 1971)

	NER May 12	MDC May 12	MDC May 13	MDC May 18	MDC May 19	NER May 26	MDC May 26
Dissolved Oxygen	12.1	X	11.6	10.5	X	9.7	9.4
Turbidity	3	5.5	X	5.0	6.0	2	4.2
Color	20	26	26	25	23	25	25
Hardness	29.7	X	32	X	34	25.6	32
pH	6.9	7.2	7.1	7.1	7.1	6.9	7.2
Iron	0.00	0.03	X	X	0.05	0.00	0.25
Manganese	0.01	0.00	X	0.00	X	0.00	X
Orthophosphorus	0.01	0.02	X	X	0.07	0.01	X
Nitrate Nitrogen	0.14	0.38	X	X	0.30	0.18	X
Nitrite Nitrogen	0.00	X	0.10	X	X	0.002	X
NH_3 Nitrogen	0.50	X	0.58	X	0.50	1.18	X
Specific Conductance	71	77	77	93	X	84	X
Fecal Coliforms per 100 ml.	750	1600	1000	1300	4000	0	3000
Total Coliforms per 100 ml.	12000	5500	6400	8000	15000	44	4400

small-scale laboratory study conducted by the MDC. This study indicated that over a 50% drop in turbidity in 24 hours was observed in undisturbed Connecticut River waters. Differences in turbidity readings indicated in Tables 21 and 22 may therefore be partly or wholly explained by a settling out of some turbidities between the two sampling sites used for the collection of these data. Thus differences in turbidity data underscore the importance of conducting future settling studies in these waters, especially in the upper pool of the Northfield Mountain project.

In an effort then to define general water quality trends and patterns more completely, to place individual data in a more general perspective, and finally to inquire into possible reasons for discrepancies in accumulated data, comparisons of selected physical, biological and chemical data are presented below. These comparisons deal specifically with values from Connecticut River waters during freshet flow, even though all values which have been available for the Connecticut River and other systems studied, have been examined.

(1) Turbidity

Table 23 compares turbidity values (J.T.U.) obtained by NER, the Massachusetts Department of Public Health, the MDC and Webster-Martin, Inc. (see Appendix 5 for specific references). The Webster-Martin (W-M) values are 24-hour averages of readings taken above Vernon Dam.

It is evident that differences in instruments and station locations may account for major discrepancies in these data. When these differences are taken into account, there is a remarkable similarity between the analyses conducted by the various agencies. However, it would be a mistake

Table 23. Comparison of Turbidity Values for Connecticut River Water from Various Sources for April and May 1971

Organization	Station	Method	April 1971	May 1971
NER	R-1	Spec. 20	26, 16	22, 16
NER	R-1	Hach	6, 2	3, 2
DPH	Rt. 10 Bridge	N.A.	4.4, 6.8, 3.4	4.2, 8.6, 0.8, 1.6
MDC (Quabbin Lab)	Rt. 10 Bridge	Hach	16, 15, 12, 18, 6.0, 5.5	22, 18, 5.5, 5.0, 6.0, 4.2, 3.8
MDC (Construction Division)	Rt. 10 Bridge	Hach	0.0, 6.0, 2.0	
Webster-Martin	No. 7	Honeywell W-20	5-10*	6-20*

*Daily averages over part of month; monitor inoperative for remainder of month.

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to assert that this general pattern of turbidity which was observed in 1971 is representative of patterns observed in other years. Turbidities approaching and even exceeding 100 J.T.U. have been periodically observed in Connecticut River waters (D.P.H. data, 1970; Webster-Martin, 1971). On the basis of all data considered to date, which have varied from hourly to monthly readings, it is most reasonable to presume that during freshet flow the turbidity in Connecticut River waters in the vicinity of the Northfield pumped storage intake is a variable multiple of the maximum turbidities observed in Quabbin Reservoir during the same period. The possibility that waters shall be diverted which have turbidities approaching or exceeding 100 J.T.U. does exist; however, the probability of this occurrence appears low on the basis of the most current data. A frequency analysis of given turbidity ranges would support this conclusion.

(2) Iron

Total iron values obtained from the Webster-Martin Study indicate a yearly range in 1970 of 0.1 to 3.4 ppm in Connecticut River waters about 15 miles north of the pumped storage intake. Data obtained from the Department of Public Health from samples collected about 8 miles downstream from where the Webster-Martin values were obtained indicate a range of values in April and May of 1970 of 0.19 to 0.42 ppm. In 1971, the April and May values obtained by the D.P.H. from these same stations ranged from 0.24 to 0.9 ppm. The MDC also collected samples from the same

location as the D.P.H. in 1971 and obtained values in April and May which ranged from 0.03 to 1.1 ppm. NER values obtained in the same period, but from samples collected several miles downstream from the MDC and D.P.H. sites ranged from 0.00 to 0.4 ppm.

(3) Chemical Oxygen Demand

COD values from the Connecticut River below Northfield were retrieved from the STORET System (retrieval date 71/03/09) for the years 1962 to 1968. April values throughout this period ranged from 12-66 ppm, with an average of 24.7 ppm. May values throughout this period ranged from 13-59 ppm, with an average of 22.2 ppm. NER values for COD in waters collected in April and May of 1971 from the pumped storage intake area varied very little from about 15 ppm.

(4) Nitrate Nitrogen

Values of nitrate nitrogen reported by Webster-Martin for the period June 1969 to May 1970 ranged from 0.08 to 0.39 ppm, with a mean value of 0.14 ppm. Approximately the same range of values was reported by the MDC for April and May, 1971. Values reported by the D.P.H. for April and May 1971 from samples collected from the same general area as the MDC samples were somewhat higher, ranging from 0.37 to 0.56 ppm. The lowest reading recorded by NER in the period April-May 1971 was 0.14 ppm

and the highest was 1.9 ppm. The average value of data obtained by NER in this period was 0.64 ppm.

(5) Ammoniacal Nitrogen

Values reported by the MDC for April and May 1971 ranged from 0.11 to 0.58 ppm. The D.P.H. reported values, for samples collected in the same time period and area as the MDC samples, which ranged from 0.012 to 0.110 ppm. NER values for April and May 1971 ranged from 0.32 to 1.18 ppm, the average value being 0.65 ppm.

(6) Orthophosphorus

Values of orthophosphorus reported by Webster-Martin for the period June 1969 to May 1970 ranged from 0.00 to 0.15 ppm, with a median value of 0.04 ppm. The MDC reported values for April and May 1971 which ranged from 0.02 to 0.15 ppm, NER values for April and May 1971 ranged from 0.00 to 0.01 ppm.

(7) Total Coliform Bacteria

The D.P.H. reported that April-May (1971) concentrations of total coliform bacteria in waters about 6 miles upstream from the pumped storage intake ranged from 2.8 to 3.9 log units/100 ml, with an average concentration of 3.3 log units/100 ml. MDC values obtained from the

same area and in the same time period ranged from 2.5 to 4.2 log units/100 ml, with an average concentration of 3.7 log units/100 ml. NER values for April and May, but obtained from samples collected in the immediate area of the pumped storage intake, ranged from 1.6 to 4.1 log units/100 ml, with an average of 3.6 log units/100 ml.

(8) Radioactivity

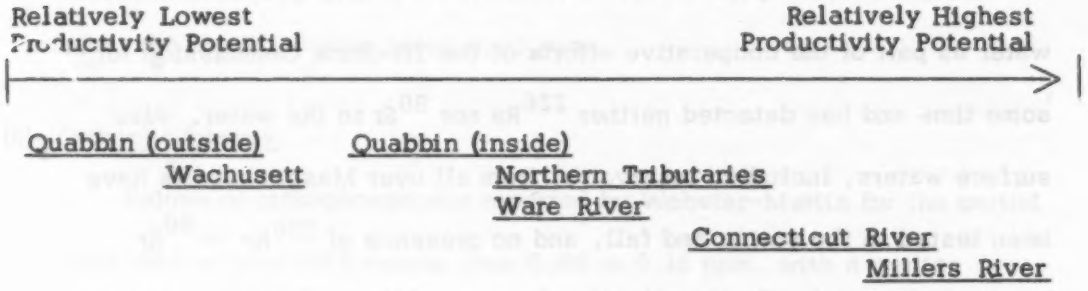
The Lawrence Experiment Station has been testing Connecticut River water as part of the cooperative efforts of the Tri-State Commission for some time and has detected neither ^{226}Ra nor ^{90}Sr in the water. Also surface waters, including reservoirs, from all over Massachusetts have been tested in the spring and fall, and no presence of ^{226}Ra or ^{90}Sr has been detected. On the other hand, some of the STORET data (retrieval date 69/06/27) for the 1960s show Connecticut River water with total beta activity in excess of 10 μμc/liter. This is not true for the more recent data.

(9) Summary Statement

The above comparisons of water quality data obtained from Connecticut River waters indicate that both small, probably unimportant, and large, probably important, differences between accumulated data do exist. The magnitude of such differences can be useful in setting individual data into perspective; however, they cannot be resolved until a coordinated monitoring program is implemented, and the present differences in time and place of water sampling are eliminated.

B. Discussion of Data

Data collected by NER from December 1970 through September 1971, as well as that generated by other public and private agencies and reviewed by NER, reinforce the idea that the various groupings of stations emphasized in this and earlier progress reports (May, August 1971) reflect a range of "productivity potential" which may be pictured, from the lowest to the highest, as follows:



As in our earlier reports, productivity is understood to mean biological productivity as reflecting a eutrophication process. Because riverine systems cannot be directly compared with lacustrine systems due to the more pronounced hydrological impact on biological processes in rivers than in reservoirs, the term "potential" implies a comparison of reservoir and riverine waters under similar quiesent conditions.

The heterotrophic bacteria are essential to nutrient recycling in lakes, and therefore to the productivity of other aquatic biota. Their presence in concentrations of up to 2 orders of magnitude higher in the Millers and Connecticut Rivers than in the other systems studied can be used as evidence of

a higher concentration of bacterial nutrients in these rivers than in the other systems. Such bacterial nutrients in turn reflect not only man-made inputs into these rivers, but also the non-living organic matter found in the same waters.

While the kinds of phytoplankton observed in all systems were similar, Millers and Connecticut River waters generally showed the most abrupt seasonal changes. This was particularly true with respect to the summer increase in green algae which included many forms usually considered indicative of "nutrient rich" waters. Species of green algae observed in the reservoir, on the other hand, are usually considered indicative of "nutrient poor" waters.

Concentrations of rotifers and crustaceans were generally lower in rivers as compared with reservoirs. This may reflect a constant flushing away of riverine organisms, thus resulting in a smaller standing crop than in the case of reservoirs. The relatively higher proportion of rotifers in the Connecticut River over the reservoirs is characteristic of the riverine environment. This was also seen at Orange and the East Branch of the Tully where the relative impoundment-like situations reflected fewer rotifers in relation to crustacea. Both rotifers and crustaceans are microphagous, tending to feed on particulate matter. Many differences in species and numbers are no doubt related to numbers and sizes of particles available for feeding. Such correlations cannot be made at this time.

Perhaps the most marked differences in benthic organisms were seen along the Millers River. The relatively large numbers of total organisms, especially

worms and the fewer numbers of species are characteristic of polluted water. Of interest is the recovery of more diversity of species downstream at Station R-10 (Farley); this paralleled the general improvement in water quality. In general, greater numbers of species are expected at rivers because of more potential diversity in habitats. The relatively smaller number for the Connecticut River may reflect the limited number of habitats that were sampled. The reservoirs had a bottom fauna that were typical both in numbers and kinds of organisms for the lacustrine environment. Seasonal variations in benthic organisms for all stations are influenced by both emergent fly populations and possible seasonal migrations (e.g. isopoda in reservoirs). These are complex patterns and not understood at present.

Essential to biological productivity, of course, is carbon. One measure of available carbon is the alkalinity of water. The highest alkalinities were observed in the Connecticut River; the Millers River showed the second highest alkalinities. Reservoirs showed the lowest alkalinities.

Chemical oxygen demand is a non-specific measure of the organic and inorganic load in waters which can be oxidized. Again, the pattern of productivity described above was observed in terms of this parameter.

Phosphorus and nitrogen are also essential to bio-productivity in water, and occur in a variety of forms. While concentrations of these elements were not dramatically higher in riverine than in reservoir systems, definite, higher concentrations were observed in the rivers. This was also true for sodium and potassium, two elements which are also required by living things.

The general classification of the waters studied from "low" to "high" potential productivity, is also useful in defining the range of potential public health hazards associated with these waters as a direct result of fecal contamination. However, a number of specific public health parameters do not follow this same pattern. The presence of mercury at all sampling sites, for example, suggests that it might be reasonable to assume that mercury is a component of all waters in this region. The Massachusetts Division of Fisheries and Game report mercury levels in fish taken from Quabbin Reservoir which are comparable with levels found in fish in the Connecticut River (1971).

Similarly, because no ^{226}Ra or ^{90}Sr has been detected in a recent state survey of surface waters, radioactivity does not now appear to be a basis for comparing these different systems with respect to a public health hazard.

The public health officials, however, must be concerned with those factors that can interfere with the treatment of waters even if the factors are not direct threats to human health. Turbidity and color, for example, can interfere with the effective chlorination of waters. These and other factors to be considered in the possible treatment of waters will be discussed in the following impact sections.

In general, the waters of the two potential donor systems are of poorer quality than those of the two receiver systems. More specifically, some constituents of the Connecticut River (e.g. ammonia nitrogen) at certain times, exceeded the recommended standards of the U. S. Public Health Service

(USPHS, 1962) or the permissible criteria of FWPCA (1968) for drinking water. The rationale for even considering such waters as potential sources of drinking water rests with both the treatment plant capacity of a reservoir (see Section I) and the total judgements on public health hazards. This issue is discussed in detail in later sections.

8. IMPACTS OF PROPOSED DIVERSIONS

A. Impact Statements and Public Policy

Every piece of legislation undergoes a process of maturation whereby its aims, intent, and procedures become more precisely defined. Public Law 91-190, otherwise known as the National Environmental Policy Act of 1969 (NEP Act), is no exception. Executive, legislative, judicial, and public review of this major legislation continues at an ever quickening pace. The results have often been dramatic. Most recently, the U.S. Court of Appeals for the District of Columbia (102 Monitor, September 1971) held that the U.S. Atomic Energy Commission must undertake a major revision of its rules governing consideration of environmental issues required under the NEP Act. Three months earlier the Council on Environmental Quality (102 Monitor, May 1971) issued revised guidelines to federal agencies on how to handle environmental impact statements in light of additional legislation as well as initial judicial decisions in cases involving Section 102 (2) (C) of the NEP Act. These revised guidelines include a directive to federal agencies "to maximize public information about environmentally significant programs so that the public's views can be considered", (Council on Environmental Quality, 1971).

Out of these and numerous other instances of review of the NEP Act have emerged certain clarifications which are essential to the environmental study here under consideration. Two clarifications are particularly important:

(1) Protection of the environment is not the exclusive goal of the NEP Act. The NEP Act is to ensure that environmental costs and benefits assume

a proper place along with other considerations in the decision-making process.

(2) Research on the environmental impact of projects is not to be used to justify decisions already made, but rather, the decisions are themselves to be influenced by research.

The fact that these clarifications have had to be made is ample proof of another fact; that the purposes of Public Law 91-190, as stated within the legislation itself, have been largely misinterpreted.

There are four stated purposes in Public Law 91-190. They are:

(1) to declare a national policy which will encourage productive and enjoyable harmony between man and his environment,

(2) to promote efforts which will prevent or eliminate damage to the environment and biosphere, and stimulate the health and welfare of man,

(3) to enrich the understanding of the ecological systems and natural resources important to the Nation,

(4) to establish a Council on Environmental Quality.

What recent national experience with the NEP Act has forcefully established, then, is that the NEP Act is to be used to achieve not simply a harmony between man and his environment, but a harmony based upon man's understanding of his environment.

It is certainly not presumed by the NEP Act that we do understand ecological systems, and that we therefore have the requisite knowledge to justify decisions affecting the environment. The presumption is to the contrary.

President Nixon himself, in his Message to the Congress which accompanied the First Annual Report of the Council on Environmental Quality (August 1970) recognized the deficiencies of present knowledge: "Existing systems for measuring and monitoring environmental quality are still inadequate. There also is a great deal yet to be learned about the significance of these facts for the human condition." In short, no impact study is an adequate impact study, under the NEP Act guidelines, which addresses itself to any question other than "what will happen, in light of the scientific understanding and facts that we now have, should a certain activity be undertaken".

The task of any impact study is therefore doubly difficult. It is not enough to present scientific facts. The scientific context and meaning of those facts must also be presented, and presented in such a way as to satisfy the sometimes conflicting requirements of both the scientific and non-scientific communities.

The number of disciplines involved and the amount of raw data (approximately 2,500 pages of raw data) generated by the present study, together with the limitations of time and space, certainly preclude any exhaustive development of all the scientific qualifications involved in any understanding of the significance or meaning of each parameter or groups of parameters. However, certain of these parameters are of such contemporary concern and/or scientific complexity that particular attention must be given to an explanation of the present "state of the art" of ecological knowledge in which they play their part. Topics selected for this more extensive treatment are: (1) viruses, (2) pesticides, (3) mercury, (4) radioactivity, and (5) bacteria.

(1) Viruses

In the last decade considerable advances have been made in the study of viruses in the water resource. Yet it is still common to note the preface, "Uncertainties still exist concerning the virus hazard. . ." in current research efforts. As the accelerating need for water continues, the environmental engineer is still plagued by several basic problems in evaluating the hazard of viral transmission in water resources.

This section will review briefly the current status of the public health hazards associated with viruses in the water resource.

What viruses capable of infecting man may be spread through water?

First, some of the basic properties of viruses must be understood. Viruses are a molecular complex consisting of a nucleic acid core and a protein coat surrounding the core. The viruses are usually spherical, having diameters ranging from 10 to 100 millimicrons. Viruses are generally resistant to a low pH of 3.0 and lipid solvents such as ether. In a water environment, viruses probably exist as aggregates of varying numbers and may be embedded within organic debris or may adhere to various particles. Most important is the fact that viruses must have a living host or cell in which to multiply. Consequently, viruses infectious to man would probably not multiply in the water environment.

About 100 different viruses may be isolated from human feces. These may be grouped into the enteric viruses, including the polioviruses,

Coxsackieviruses, and echoviruses; the virus(es) of infectious hepatitis IH; the adenoviruses; and the rheoviruses. As yet, the viral agent(s) of IH has not been isolated.

In addition to the above, the viruses of non-human animal origin must also be considered as a potential source of infection to man, since it is possible for them to find their way into water supply systems.

According to Mosely (1965) of the Public Health Service National Communicable Disease Center:

> Any virus excreted in the feces and capable of producing infection when ingested should theoretically be transmissible in drinking water. Waterborne transmission has accordingly been suspected for enteric virus thought to be transferred from person-to-person by the fecal-oral route. We now know, however, that some viruses transmitted by the respiratory route are also excreted in the stool in quantities detectable by tissue culture techniques. The agent of rubella is a recently demonstrated example (Green, et al., 1965). Past experience has indicated that the circumstances under which contaminated water may be used for drinking are almost as numerous as the ways in which drinking water may become contaminated. It is conceivable, therefore, that at some time almost any virus can be transmitted through water.

It must also be assumed that diseases listed as "viral gastroenteritis" can be transmitted via the water route, even though attempts to isolate the causative agents have failed. Typical of many reports is one according to Jacobson (1970) in which a small village near Buffalo, N.Y. suffered a wide-spread outbreak of gastroenteritis. The water source for the affected area came from Lake Erie and was processed by a water treatment plant

utilizing rapid sand filtration and sedimentation. "Specimens from multiple sources in the water supply and stools from ill subjects were all negative in bacteriologic, virologic and chemical analysis" according to the report, yet the "characteristics and distribution of this illness, as well as its relationship to the water treatment plant and its distribution lines, clearly pointed out the waterborne nature of this outbreak".

The capability of the infectious hepatitis virus(es) to infect man through drinking water is well documented. Therefore, it may be concluded that IH, and the enteric viruses and possibly the causative agents of viral gastroenteritis may all be transmitted by drinking water.

Compared to more direct means of contracting viral disease, the water route is generally agreed to present a far lower hazard in terms of reported cases. Yet according to Berg (1967), the amount of virus that can infect man is often equal to or smaller than the amount of virus that can infect susceptible cell culture systems. Thus any amount of virus detectable in water is likely to be sufficient to infect susceptible individuals.

In this country, where adequate disinfection practices are in general usage, the documented waterborne outbreaks of infectious hepatitis are very small in number, yet epidemiological studies are often hindered since many sub-clinical cases can go unreported. It is pertinent to note here that the great outbreak in New Delhi in 1955-1956 resulted from a water supply which met acceptable coliform standards.

How are water supplies monitored for viruses?

The literature shows clearly that routine monitoring of water for virus is difficult and costly, and for the near future, at least, is an impossible task for the average water laboratory. Analysis requires the concentration of often large quantities of water (100 liters or more at times) and subsequent extraction or elution of the viruses onto tissue cultures at appropriate dilutions. Examination of the cultures for evidence of cell abnormalities shows the presence of virus and the specific titer may be thereby determined.

In the past, most monitoring involved the "swatch test", in which a gauze pad was left suspended in a water source for a period of time and the viruses would be later eluted from it for analysis. Although the presence or absence of virus in the water can be ascertained by this method, it does not give any quantitative information and its sensitivity is open to question.

More recent work has been done with a variety of materials by which the water sample may be concentrated. Polyelectrolytes, coagulants, cellulose-acetate (Millipore) filters, etc. are some of those now being evaluated. It is to be hoped that these more promising techniques will add greatly to our understanding of the concentrations of viruses in the natural environment.

The use of coliform numbers as an indication of virus in water would be ideal. Yet the New Delhi outbreak of infectious hepatitis clearly

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shows this to be an invalid practice. The relative numbers of coliform bacteria to viruses may vary greatly in polluted water. Clarke, et al. (1964) calculated the average virus density in domestic sewage to be about 500 virus units per 100 ml, and in polluted surface water not more than one virus unit per 100 ml. Coliform densities in domestic sewage average 46 x 10^6 per 100 ml, and in polluted surface waters they average between 10^4 to 10^5 per 100 ml. Thus, these authors agreed upon a coliform-virus ratio in sewage to be approximately 92,000:1 and in polluted surface waters, about 50,000:1. Apparently then, because the coliform numbers are much higher than viruses, the coliform numbers would be a better indication of the presence of viruses in non-polluted waters than actual virus analysis (should similar ratios hold for non-polluted waters).

However, several factors rule out the effectiveness of the coliform numbers as an indication of the presence of virus. First, new techniques of virus detection may well show higher numbers to be present in water than has been heretofore believed, thereby developing a situation similar to that of the much discussed mercury pollution. Then too, the relative survival rates of bacteria to viruses may vary greatly from virus to virus and even in different qualities of water. Add to this the New Delhi incident and one may reject completely the use of coliform numbers as quantitative or qualitative indicators for the presence of viruses in water. Although a positive coliform index must indicate the possibility of viruses to be present in water, a negative coliform index may not indicate the absence

of viruses (Committee on Environmental Quality Management, 1969). In this respect, a better assurance of the absence of viruses in water may be given by low turbidities and good chlorination as will be discussed later. Otherwise, positive tests for the presence of viruses in water must ultimately depend upon actual testing for viruses directly.

What is the effectiveness of sewage treatment processes in the elimination of viruses?

Research in this area is generally inadequate in presenting absolute values for virus removal by each process. Chiefly, this is due to the inadequacy of different laboratories in using similar or comparable techniques and standards for virus analysis and evaluation. Then too, since most research in this field involves the addition of one or a few laboratory-prepared viruses to a treatment influent and then analysis of the effluent for the virus, objections may be taken as to the validity of the assumptions made in these tests. It may be more realistic (although very costly and considerably time-consuming) to test the treatment process for the elimination of those viruses occurring naturally in the wastewater.

The efficiencies of virus removal for the various treatment techniques are listed below:

(a) Primary treatment - This process removes very little of the viruses present in sewage. According to Berg (1971), only 0-3% of poliovirus type I added to the raw sewage, was removed after a three-hour settling period, although greater than 50% solids had been removed.

Greater retention times can remove more of the virus, however, but removals of better than 70% are impractical and not consistent.

(b) Activated Sludge - A variety of reports show inconsistent removals of virus up to 90% (Sproul, et al., 1967). Yet it must be noted that the viruses are not killed by this process and others which involve actually separating them from the wastewater. The ultimate disposal of the viruses must also be considered.

(c) Trickling Filtration - Although some removals may occur with this process (reported up to 40%), it is very inconsistent (Sproul, et al.).

(d) Oxidation Ponds - Removals up to 90% may occur with this process (Sproul, et al.). However, several factors such as short-circuiting may decrease virus removal. In addition, since the actual relative survival times of the many viruses are not known under differing environmental conditions or even standard conditions, this process deserves more research for a definite statement.

(e) Adsorbents - A variety of materials such as activated carbon, bentonite, polyelectrolytes, clay particles, ion exchange resins, etc. may adsorb viruses to their surfaces, thereby removing them from water. The virus-adsorbent bindings show varying degrees of strength and some allow a final elution of the viruses from the adsorbent. These processes may vary in their effectiveness with the concentration of many different solutes and with differing turbidities. Generally, their maximum effectiveness is only reached after parallel treatment operations.

(f) Filters - A filter must obviously have a pore size of less than 10 mμ in order to eliminate viruses from water. Such filters are very costly and can operate usually only under highly controlled conditions.

(g) Coagulants - Viruses may be precipitated by the use of additives such as $Al(OH)_3$, phosphates, and lime, and removals may attain 90% or better (Liu, 1971). Yet again, this process reaches maximum efficiency only with controlled conditions and with other, parallel treatment.

(h) Disinfectants - Free chlorine, hypochlorite, bromine and ozone may all be used to destroy waterborne viruses. The relative rates of inactivation of the different viruses by free chlorine is currently being examined by Liu (1970) and others. In general, for 99.99% devitalization by 0.5 mg/l of free chlorine, survival times vary greatly from several minutes to 36.5 minutes for poliovirus type 2. The Committee on Environmental Quality Management (1969) believes that a high level of protection is afforded by chlorination of secondary treatment effluent to a level producing an amperometric chlorine residual of +5 mg/l after 30 minutes of contact.

(i) Other Processes - Chemical reactions, ultraviolet light, temperature, and other natural and employed processes within the water environment may all affect the survival of viruses. Water samples containing viruses may be stored for several weeks to months and retain their infectious properties. It is in this basic area that work must be continued to fully understand the ecology of waterborne viruses.

It may be concluded that although data are still incomplete, virus elimination up to 99.99% removal may be attained by using the best treatment processes available, followed by good free residual chlorination. It is to be noted that even the best of the conventional treatment practices may produce an effluent which may still contain infectious viruses. The discussion of Shuval (1967) of the possible significance of low concentrations of viruses is pertinent:

> The findings of Dr. Lund, confirmed by the research in South Africa, that sewage treatment plants reduced the viral content of sewage by 1, or possibly 2, logs added to the estimate of Dr. Coin that one infectious dose of virus was present in 250 liters of Paris drinking water, provoke speculation. If the viral concentration in a sewage is 10 $TCID_{50}$/ml, and this amount is reduced by as much as 2 logs in a sewage treatment plant, another 3 logs by dilution in a river, and 2 or 3 more logs in a water treatment plant, a total of 7 or 8 log reductions in viral concentration results. This leaves a water containing perhaps 1 $TCID_{50}$ (tissue culture infectious dose) of virus per 1000 liters. I suggest that this is not an unimportant amount. It is true that one person does not drink 1000 or even 250 liters of water per day, but one in 250, or one in 1000 or even one in 10,000 persons ingests 1 $TCID_{50}$ of virus daily, and 1 $TCID_{50}$ is an infectious dose for man, as Dr. Plotkin suggested, even after the viral concentration has been reduced 99.9999%, we have a level of ingestion of virus that could be responsible for a proportion of the endemic viral diseases in communities consuming highly treated waters.

What is the fate of viruses in natural water systems?

Although many studies have been conducted on the determination of viruses in sewage and water under a variety of chemical and hydraulic conditions, very few attempts have been made to study the effect of

drainage systems, lakes and streams, infiltration systems and the like, upon the reduction of viruses.

1. Streams and Lakes - McLean, Brown and Laak (1966) conducted a number of experiments which showed the following:

   (a) "Movement of water in creeks induces rapid dilution and thereby disperses virus infectivity, but virus concentration in stagnant lake water remains relatively unchanged for considerable periods."

   (b) Although streams may rapidly disperse the virus content, "continuous addition of virus over a prolonged period, for example, infectious hepatitis virus in unchlorinated sewage effluent, into a slowly moving river increased the hazard of infection to such an extent that six of nineteen subjects at Bathurst, Australia (Wallace, 1958) contracted infectious hepatitis after drinking river water contaminated by sewage. Similarly, slowing of water movement to stagnation point in the upper Illinois River near Chicago, permitted the accumulation of enteroviruses both upstream and downstream from sewer outfall (Lamb, et al., 1964)."

2. Overland Flow - According to Liu (1971), "this system does not include any obvious step which can safeguard a high order of viral elimination". The system is difficult to assess since many processes and variables are involved, such as aging, adsorption onto clay particles, and a variety of other environmental conditions. Although some types of clay may adsorb viruses, others may not. It is

known that sand or soil columns may freely permit the passage of poliovirus type 3, (McLean, et al., 1966).

3. Infiltration Basins and Spray Irrigation - Again the types of soil involved may offer varying degrees of viral adsorption capabilities. Liu suggests that intermittant rates of filtration may be beneficial to the retention of virus, but again, the system does not provide any assured removal of virus.

It must be assumed that the recreational use of any of these systems could potentially involve hazards. However, the Santee, California project is a well-known example of what can be done in the way of removing viruses to provide recreational resources using treated water (Culp, 1971).

Summary

It is essential to understand that while there is much confusion among scientists about the public health hazards to be associated with surface waters, practical experience with public water supplies suggests that much of the concern expressed over the dangers of viral agents in water supplies is academic. For example, the Massachusetts Department of Public Health has carefully monitored the public health effects of the consumption of water taken from the Merrimack River by the cities of Lawrence and Lowell. No detriment to public health has ever been noted as a result of this consumtion, even though we must assume, on scientific grounds discussed above,

that viral agents are present in the Merrimack River. It is, therefore, a mistake to presume that scientific concerns are always real concerns. It would also be a mistake to disregard completely such concerns.

(2) Pesticides

(a) Basic Considerations

There are many classes of pesticides, including those intended to kill or control plants, invertebrate animals, and vertebrate animals. The types that concern us most are herbicides and insecticides. These chemicals are used in large quantities, they are spread over large areas, and hence they may come eventually in direct contact with surface waters. The Federal Insecticide, Fungicide, and Rodenticide Act provides for their registration and use.

Herbicides are used to control plant, weed and algal growths in both the terrestrial and aquatic environments. A variety of both organic and inorganic herbicides are used. Herbicides used in the aquatic environment include such organic chemicals as 2,4-D. Others may enter surface waters through run-off. Persistence in the environment may be as long as several months. One convenient classification of insecticides is based on persistence in the environment. Some organochlorine insecticides, of which DDT is perhaps the best known, persist for a long time (years). Others, like the organophosphorus compounds are chemically more labile and undergo rapid breakdown in the environment.

Of major concern, then, are such considerations as persistence, general concentrations in the environment, and toxicity. An understanding of these points is necessary before estimates of any public health hazards or environmental impacts can be made.

So important is the question of harmful effects of pesticides, that a special report on the Ecological Effects of Pesticides on Non-Target Species was prepared through the President's Office of Science and Technology (Pimentel, 1971). Another recent publication entitled Report of the Secretary's Commission on Pesticides and their Relationship to Environmental Health (so-called Mrak Report, 1969) is an exhaustive inquiry into this whole area, and the reader cannot escape the general message. Pesticides are potentially dangerous chemicals.

There is no question that some pesticides are globally distributed by the atmosphere. Both DDT and dieldrin are found in dust and rain water. The atmosphere is probably the principal source of contamination for many areas. Average concentrations of pesticides in rain water (0.1 to 0.4 ppb) is equivalent to and often higher higher than those found in river waters. Reviews of the evidence on atmospheric contamination include Frost (1969) and Wurster (1971). Therefore, the presence of pesticides in surface waters need not reflect their use in the immediate vicinity.

In addition, pesticides may be found in the tissues of both plants and animals. Persistent insecticides have very long half-lives in the

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environment; it takes a very long time for 50% of the chemical to disappear. Compounds such as DDT also have long half-lives in the human body. Thus, a compound which disappears slowly from the environment or the body is subject to accumulation when the input exceeds the losses.

Another important consideration with persistent pesticides is the tendency for the compounds to be concentrated by successive steps in the food chain (National Academy of Sciences, 1970). Progressive stages of the food chain (plankton, herbivores, primary carnivores, etc.) concentrate the pesticide chemicals. Several log units greater concentration in tissues above ambient concentrations in water are achieved. Hard pesticides are extremely insoluble in water, and tend to disappear from water due to evaporation into the atmosphere, precipitation to the bottom sediments, or uptake by animals and plants. A good demonstration of these characteristics can be seen in an experiment in Ohio, where a marsh was sprayed with radioactive DDT (Peterle, 1969). The highest levels in surface waters were found one hour after application, and dropped below detectable levels in two weeks. Concentrations in the mud remained constant for over a year, and rooted plants showed a slight rise in concentrations of DDT two years later. Maximum concentration in one type of alga occurred one week after application; the algal concentration of DDT was 3000 times the

initial concentration in the water. Thus, whereas concentrations of hard pesticides in surface waters rarely exceed 1 ppb, levels in living tissues may be routinely in the range of 1-10 ppm.

As a general rule herbicides and insecticides are relatively non-toxic to mammals with respect to acute effects. Oftentimes lethal doses are several hundred mg/kg body weight (Pimentel, 1971). Conversely, fishes and other aquatic organisms are more sensitive, with lethal concentrations often in the range of 1 ppb in water. Therefore, pesticides may often present potential hazards to the ecological balance of a given ecosystem, without presenting a public health hazard to man.

(b) Potential Hazards to Man

In discussing human toxicology, it is essential to distinguish between the organophosphates and the chlorinated insecticides, and between acute and chronic effects.

Very poor information on the toxicity of hard pesticides like DDT to humans exists. More is known about acute effects than chronic effects. Accidental ingestions of DDT in gram amounts are not fatal (O'Brien, 1967). This implies that a human could ingest 1,000,000 liters (250,000 gallons) of water containing 1 ppb of DDT without running the risk of acute toxic effects. The toxicity data of most hard pesticides on mammals would indicate that the potential hazards

to man from ingestion of water supplies is virtually non-existent. Similar conclusions can be drawn from the toxicity data on such herbicides as 2,4-D and 2,4,5-T.

The organophosphorus insecticides, however, present another picture. Closely related to the so-called "nerve gases", these compounds are very toxic to both mammals and lower forms. Trace amounts can be toxic, and cases of accidental poisoning in humans are well known. However, because of ester linkages, these compounds undergo relatively rapid breakdown. Hence, persistence and potential accumulation are not potential problems. Possible exceptions are parathion, which degrades more slowly, and some intermediate degradation products which have greater longevity than their parent pesticides, and whose toxicity is relatively unknown (Chesters and Konrad, 1971).

The chronic effects of pesticides are relatively unknown. Long-term exposure to various pesticides is a major concern of the Mrak Report (1969). There are difficulties in extrapolating from studies with adult human males to females, children and fetuses (Wurster, 1971). Pesticides, in common with many chemicals, can influence metabolism (Kraybill, 1969). Such problems, however, are not unique to public water supply issues. They encompass a wide spectrum of public issues, and at this point in our knowledge we must be aware of the possibility of such chronic effects in man. Human exposure to hard pesticides comes primarily from foods, rather than drinking water.

(c) Ecological Effects

The ecological effects of pesticides are now widely appreciated, even though the full impacts of some trace amounts are not known. The literature is full of warnings on the hazards to some species, especially from the more persistent pesticides (American Chemical Society, 1966; O'Brien, 1967; Wilber, 1969; Pimentel, 1971). It is difficult to generalize because of species differences, toxicity differences among chemicals, and the potential influences of other factors. However, some animals are affected by very small concentrations. Experiments at Lake George showed that 100% mortality of lake salmon fry occurred when DDT was present in the eggs at concentrations of 5 ppm (Mrak Report, 1969). In addition, there is evidence that the biological magnification of DDT and dieldrin residues in food chains is causing reproductive failure in predatory birds (Shea, 1969). Toxic effects are not limited to animal species, since DDT in concentrations of 1-10 ppb can also reduce photosynthesis in algae (Wurster, 1968). Many ecosystems may be at or near the level at which pesticide residues are damaging to the more sensitive species.

In conclusion, then, trace amounts of pesticides present mainly potential environmental effects, rather than public health hazards associated with water supplies. Because of the behavior of pesticides in the environment, potential contamination of the environment will be reflected not only in water concentrations, but also in sediments and

particularly in animals near the end of the food chain. Therefore, for purposes of this report, pesticide levels in both water and fish tissues will be discussed in a subsequent section.

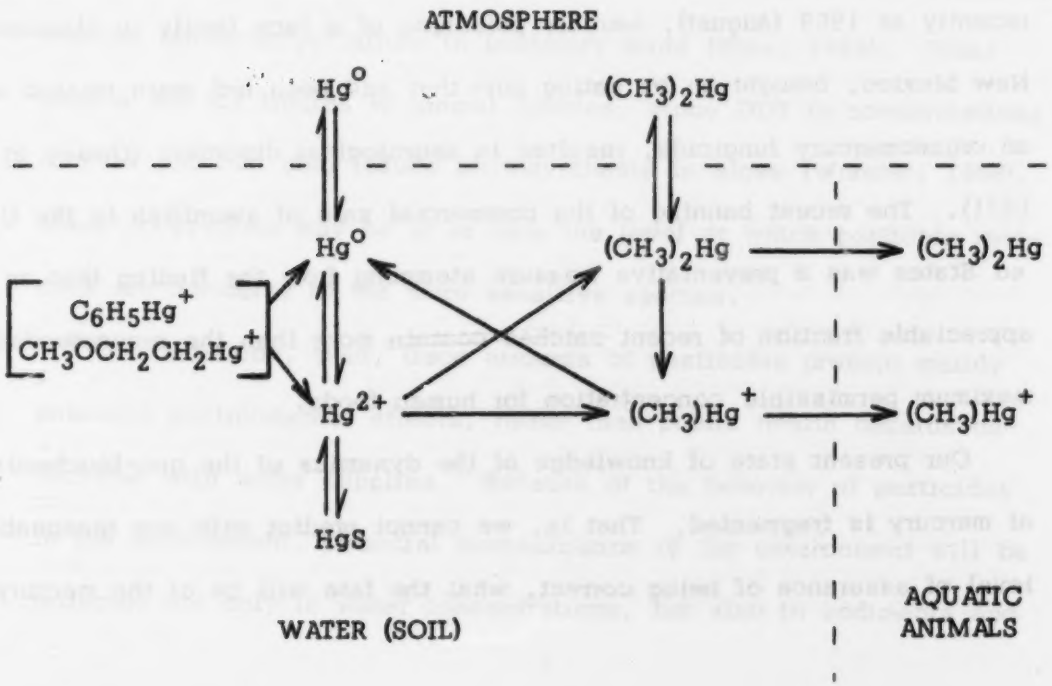
(3) Mercury in the Environment

Recent reviews (Wallace et al., 1971; Oikos Suppl. 9, 1967; Miller and Berg, 1969; Stahl et al., 1969) have outlined the major aspects of the mercury-environment-man interactions. It is now clear that the industrial uses of mercury, primarily its use as a cathode in the chlorine-sodium hydroxide industry and the distribution of organomercury compounds as antifungal agents, have increased the mercury in the environment to a level that has produced many local hazardous situations, with deaths and poisonings, human as well as other animals, reported in several countries. As recently as 1969 (August), mercury poisoning of a farm family in Alamagordo, New Mexico, brought on by eating pork that had been fed grain treated with an organomercury fungicide, resulted in neurological disorders (Curley et al., 1971). The recent banning of the commercial sale of swordfish in the United States was a preventative measure stemming from the finding that an appreciable fraction of recent catches contain more than the recommended maximum permissible concentration for human foods.

Our present state of knowledge of the dynamics of the geo-biochemistry of mercury is fragmented. That is, we cannot predict with any reasonable level of assurance of being correct, what the fate will be of the mercury

already introduced into the environment. The rate with which mercury passes from the natural and man-made terrestrial sources to long-term stabilization in sinks is unknown. The influence that the natural production of dimethylmercury (and other organomercury species) in anaerobic environments has on the pathways from sources to sinks is not clear.

Mercury may exist in nature as the metal Hg^{o}, as inorganic mercurous Hg_2^{2+} (generally unstable, but can be present in small amounts in several possible equilibria) and mercuric salts Hg^{2+}, and as organometallic compounds. Metallic mercury and several organomercury compounds have appreciable vapor pressures so that the atmosphere may carry significant quantities of the substances. Wallace et al. (1971) have given what they call 'transformation pathways', shown schematically in the diagram below.



They state:

> More information is certainly needed on the interconvertibility of each of these steps; nevertheless, the overall equilibria in nature tends (sic) to proceed toward the right, since the methylmercury and dimethylmercury compounds are not tightly bound to substrates, are water soluble or volatile, and are rapidly taken up by living organisms in which they are relatively stable.

The theme appears to be a recurrent one; our ability to measure a potentially toxic material is greater than our understanding of the significance of a particular level. This is complicated by the dynamics of the various transformation pathways in the environment, as shown above for mercury. Our interpretations of the public health and environmental aspects of certain levels of mercury, therefore, must be tentative. In the meanwhile, we must rely on whatever standards we now have.

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(4) Radioactivity

(a) Radioactivity in Natural Waters

Because of the universal presence of the tritium (^3H) atom as a structural component of some water molecules, and the fact that trace amounts of practically all elements are found in natural waters, natural waters must show radioactivity. The amount of radioactivity of course, is the critical point. Radioactivity in water is customarily reported in $\mu\mu$c/liter, and is usually specified as alpha or beta activity. Often the exact isotopes are not identified, and it is more important to know the quantity of alpha and beta activities being emitted (Wilber, 1969). Gross alpha and beta activities reported in $\mu\mu$c/liter therefore is the standard analysis of radioactivity in natural waters.

A number of elements contribute radioactivity to natural waters, including uranium isotopes (Hem, 1970). ^{226}Ra is a disintegration product of ^{238}U. Because of a relatively long half-life, ^{226}Ra is the dominant form in natural water and contributes most of the alpha activity. Beta activity may be produced by strontium isotopes, as well as radioactive iodine, cesium, phosphorus and cobalt. By convention, when significant levels of gross beta activity are detected, specific analyses for radioactivity from ^{90}Sr are carried out. In summary, then, natural waters contain both alpha and beta forms of radioactivity. When gross levels exceed a certain amount, specific

analyses for ^{226}Ra and ^{90}Sr are carried out.

(b) Current Standards

The FWPCA Water Quality Criteria (1968) and the USPHS Drinking Water Standards (1962) list specific recommendations for radioactivity levels in water. Drinking water standards set a maximum gross beta activity at 1000 μμc/liter, alpha activity from ^{226}Ra at 3 μμc/liter, and beta activity from ^{90}Sr at 10 μμc/liter. Desirable criteria are listed as <100 μμc/liter, <1 μμc/liter, and <2 μμc/liter, respectively. Water quality criteria for freshwater organisms are also specified. Radionuclides should not be present at concentrations greater than those specified by the USPHS Drinking Water Standards.

(c) Potential Hazards to Man

There is no question about the public concern over radioactivity. Radioactivity is invisible, it is technically difficult to understand, and it has dramatic overtones resulting from the continual publicity of atomic energy. Lack of agreement among scientists as to safety measures contributes to the sense of apprehension among the public, and results in a general lack of confidence in scientific judgments. A case in point may be seen in some of the proceedings of a conference on Nuclear Power and the Environment held in Vermont (Atomic Energy Commission, 1969).

At this same conference the question of safety from radiation was discussed, and it was pointed out that a man living near the edge of a reactor would receive an additional dose of 5 mrem (milliroentgen-equivalent-man) per year. This is one percent of the current maximum permissible exposure of 500 mrem/year. Normal exposure of the population ranges from 80 to 200 mrem/year. We agree that this case represents a reasonable risk, as the maximum permissible exposure is the point where there is no evidence of any radiation damage to humans.

Turning our attention to water, concentrations of radioactive materials must be translated in terms of exposure resulting from either ingestion or contact. One of the problems is the correlation of radiation dose equivalence with the concentration of tritium in water (Moghissi, 1970). At any rate, the operation of a major nuclear facility on the Savannah River is estimated to add a tritium concentration of 4 μμc/liter to the water which is used as drinking water in Beaufort, S. C. This corresponds to 0.8 mrem/year, or 0.5% of the average annual dose. It is also less than 0.2% of the maximum permissible concentration.

The pathways through which radioactive materials may reach man are very numerous (Straub, 1970). The concept that man is surrounded by a sea of dilute radioactivity, and that his own body is radioactive (Atomic Energy Commission, 1969) are important to

bear in mind. However, these facts do not argue against a concern for radioactivity. They merely reinforce the need for objectivity and a willingness to understand the risks involved in any project involving atomic energy. We still cannot fully predict the public health implications. We can only state them in probabilistic terms.

(d) Environmental Implications

The fate of radionuclides in a stream is determined largely by the normal chemical, physical and biological processes taking place within the stream (Straub, 1970). Radioactive chemicals enter into metabolic cycles and food webs just as the chemicals without radionuclides. Accumulation of radioactive materials is of great concern to biologists, because of the accumulation through the food chain of valuable species (Warren, 1971). Studies have shown that the accumulation of radioactive materials in fish tissues may affect the the life span and growth rates of fish. The accumulation in aquatic organisms may be by three ways: (1) ingestion, (2) absorption, and (3) adsorption to surfaces (Mackenthun, 1969). The uptake may be fairly rapid, as seen with the maximum uptake of radiophosphorus by algae in 18 days. In general, the radioactivity decreases as one progresses in the food chain. However, the amounts of some radionuclides in tissues can still be considerably over that of the surrounding water.

At the same conference in Vermont mentioned above, a question (p. 117) as to absolute certainty that radioactivity will not harm microorganisms in the environment was raised. Of course absolute certainty cannot exist, but the answers stressed the lack of evidence over many years for changes attributable to the accumulation of radioisotopes. In the same series of statements, the need for continual monitoring was also stressed. One important point is worth stressing in this connection. The available evidence strongly shows that the concentrations of radionuclides in fish and shellfish that would limit their use as food are substantially below the concentrations that would injure the organisms from radiation (FWPCA, 1968). Therefore, there is no need to establish separate criteria in water beyond those needed to limit the intake by humans. Thus public health factors appear to outweigh environmental effects for radionuclides in the aquatic environment.

(5) Bacteria

The bacteria present at any time in natural waters are usually considered in three categories (Collins, 1960): (1) those washed in from outside sources, of which a large proportion will ultimately perish, but some will find conditions suitable for growth; (2) "indigenous" types capable of existence in a dilute nutrient solution as represented by lake water, and able to use for growth low concentrations of available organic matter; and (3) those dependent on a solid surface for their proliferation and therefore found in connection with soil particles, mud detritus and plankton. Category (3) may be inclusive of category (2).

Methods of water bacteriology have been described in a series of methods manuals and monographs on general and aquatic microbiology (Fred and Waksman, 1928; Zobell, 1946; Rasumov, 1947; Frobisher, 1962; Vollenweider, 1969; A.P.H.A., 1971).

It is not intended here to give a full account of all bacteriological methods used in aquatic bacteriology. Our goals here are twofold: (1) to give the reader an insight into how the methods of this study compare to the "state-of-the-art", and (2) to enumerate some of the considerations which must be evaluated in interpretation of bacteriological data.

Methodology

The study of aquatic bacteria has taken two main courses. One has been the study of heterotrophic bacteria, and their enumeration and relation to mineral cycling. The other has been the use of certain bacterial groups,

e.g. coliform, as indicators of sanitary conditions. While the methods of analysis for coliform enumeration and identification are fairly standardized, the methods applied to studies of total bacterial populations are many and varied.

(A) Culturing Techniques

A number of early aquatic microbial studies using culturing techniques for enumeration of bacteria have been reported (Fred, Wilson and Davenport, 1924; Snow and Fred, 1926; Graham and Young, 1934; Henrici, 1938). These studies were mostly enumerative in nature with only limited consideration given for the methods used. It was later recognized that neither one single medium nor any one set of cultural conditions would support the growth of all "naturally occurring" heterotrophic bacteria (Zobell, 1941; Carlucci and Pramer, 1957). Subsequent investigations have compared various counting methods, both viable and direct counts.

1. Plating Methods

Carlucci and Pramer (1957) compared pour and spread plating techniques with media of varying composition for marine bacteria. They found the number of bacterial colonies that developed on pour plates was greater by 30 to 40% than the number that developed on surface innoculated plates. They reported, however, that colony counts were made more easily with a surface innoculum due to larger, more uniform and better distributed colonies.

Buck and Cleverdon (1960) had contrasting results to Carlucci and Pramer (1957). Their spread plates always revealed higher counts. The ratio of counts, spread/pour, ranged from 1.1 to 9.5. The reproducibility was equal for both methods.

Zobell and Conn (1940) have shown that some marine bacteria are thermosensitive and are killed at the congealing temperature of agar. Conversely, Jannasch and Jones (1959) found no direct evidence that the heat of the agar adversely affects the microorganisms developing on agar plates.

A number of studies (Carlucci and Pramer, 1957; Floodgate, 1964; Jones, 1970) have found that the composition of viable count media exerts an effect on the count estimate. A recent publication (Jones, 1970) compared media recommended by the American Public Health Association (1965) with the casein-peptone-starch (CPS) medium of Collins and Willoughly (1962). Their results were reported for 4 to 6 samples from 5 freshwater systems with 5 or more replicas for each. They found tryptone-glucose-yeast extract (TGE) and Plate Count Agar gave higher counts on 85% of the samples at 48 hr. incubation (20° C), but only 20% of the increases were statistically significant. At prolonged incubation (14 days, 20° C) higher counts were obtained on CPS with 96% of the samples, of which 74% were statistically significant. At lower temperatures (10° C, 23 days) the counts on

CPS were higher with 84% of the samples and all were significant. They concluded that under the specified growth conditions CPS is more suitable for counts of freshwater bacteria than the recommended media of the American Public Health Association (1965).

2. Membrane Filters

A number of investigations have used membrane filters for culturing and enumeration of bacteria. These include bacterial counts from sediment (Anthony, 1970), microcolony counts (Jannasch, 1958; Jannasch and Jones, 1959) and plate counts (Bennett, 1969) for planktonic bacteria. Membrane filters have an advantage in allowing an investigator to concentrate a sample. This is especially beneficial in areas of low bacterial populations. Where 0.1 ml and 1.0 ml of innoculum are usually used for spread and pour plate, respectively, bacteria from up to 100 ml or more of water can be filtered on a membrane filter.

Windle Taylor and Burman (1964) published an article on membrane filter application and techniques. They compared 3 types of membrane filter (each manufactured in a different country) for different properties. Among their findings were the following:

(a) Spreading of colonies rarely occurs on the American filters with nutrient broth as a medium. Profuse spreading at 37° C,

but rare spreading at 22° C was characteristic of the British and German filters.

(b) Colony spreading is closely related to moisture control. Excess moisture encourages spreading, but too little moisture causes poor colony growth.

(c) The use of absorbant pads instead of agar as a method of media application is recommended for economical reasons.

They concluded that with membrane filters results can be obtained in a shorter time (for some tests) than standard techniques. They also effect marked savings in the amount of culture media and glassware used, as well as savings of time and labor in the laboratory.

There was little mentioned about a comparison of results between membrane filter and other techniques.

(B) Direct Counting Methods

Direct microscopic counting of bacterial populations is generally recognized as a most important technique in determining microbial growth rates and assessing population numbers (Collins, 1963; Jannasch and Jones, 1959; Jannasch, 1965).

1. Artificial Substrates

The use of artificial substrates in microbial ecology has simplified direct counting procedures. The substrate most commonly used in both aquatic and soil microbiology has been the glass

slide (Cholodny, 1930; Sladecekova, 1962). Glass slides, though, have led to difficulties in use because they cannot be removed and replaced without disturbing the environment and it is difficult to observe a living organism. Hence, isolation and subsequent cultural study is almost impossible.

Other studies (Collins and Kipling, 1957; Perfilyev and Gabe, 1969) have used capillary tube techniques. This method has some advantages over glass slides. These can be found in a book by Perfilyev and Gabe, 1969.

2. Membrane Filters

The use of membrane filters for direct counts involves the filtering of a known volume of water through the filter. The membrane filter is then dried and stained for microscopic examination. Richards and Krabek (1954) have employed a phase microscope for counting microorganisms on the filter.

Membrane filters were first suggested for the enrichment of bacterial plankton by Cholodny (1929). Subsequent investigations showed that the use of culturing techniques for the enumeration of bacterial populations accounted for only a fraction of the true population.

Butkevich (1938) and Salimovskaga-Rodina (1938) showed that direct counts gave 200 to 5000 times higher counts than plating methods. Kusnetsov (1958) using viable staining methods estimated

that 10% of the bacteria counted by direct methods were non-viable. A study by Jannasch (1958) suggested the type of natural water sampled influences the degree of discrepancy between plate counts and direct counts. He showed the differences between plate and direct counts to be four times greater in "highly contaminated areas" than in "rather clean sections" of a river. Jannasch suggests the discrepancies are due to the tendency of planktonic bacteria to clump on the surface of suspended solids in natural waters.

Zobell and Anderson (1936), Stark, Stadler and McCoy (1938) and others have shown the attachment of bacteria to suspended solid surfaces follows previous adsorption of soluble organic matter. Henkelekian and Heller (1940) showed that the growth of bacteria in the presence of suspended solid surfaces depends on the concentration of soluble nutrients present.

Attempting to overcome the problem of clumping, Jones and Jannasch (1959) used surface active agents to remove the bacteria from particles, but Buck and Cleverdon (1960) were unable to repeat their success. Jones and Jannasch (1959) were unable to remove bacteria from clumps by mechanical shaking.

Jannasch and Jones (1959) used 5 different cultural and 2 direct microscopic methods for estimating the abundance of bacteria in sea water. Direct counts showed the presence of from

13 to 9700 times as many bacteria as cultural methods. Their results also showed a marked decrease in bacterial numbers just below the thermocline using cultural methods but not the direct microscopic methods. An explanation may be found in the work of Kriss (1953) who found that at depths descending from the thermocline, the bacterial numbers are regulated by the concentration of organic matter. Jannasch and Jones also suggest the possibility of inactive cells at that depth.

While there are apparent advantages to direct counting methods, some disadvantages must be considered. Stumm-Zollinger (1968) found direct counting undesirable due to the inability to differentiate between particulate matter and bacteria. Direct counts cannot differentiate autotrophic from heterotrophic organisms, nor can any physiological or metabolic properties of the bacteria be studied. Thus, direct counts can contribute to the overall understanding of microbial populations, but the limitations toward investigating metabolic and physiological characteristics of the population must be recognized.

Summary and Conclusions

1. Neither spread plates nor pour plate techniques have been shown to be superior.
2. Whether or not the heat of agar in pour plates affects bacterial counts is undetermined.

3. The composition of cultural media affects the total viable count.

4. Cultural conditions (temperature and length of incubation) affects total viable counts.

5. Membrane filters have advantages of economy and better suitability for waters of low bacterial populations.

6. Moisture control is very important in membrane filter techniques.

7. The information obtained from the use of artificial substrates for population enumeration is limited.

8. The use of membrane filters for direct counts has shown bacterial populations to be up to 9700 times higher than those detected with culturing methods.

9. Discrepancies in counts are probably due to the clumping characteristics of bacteria in natural waters.

10. The limitations of direct counts are: (a) they cannot differentiate autotrophic from heterotrophic organisms; (b) bacteria cannot be isolated for further metabolic studies; and (c) it is often difficult to differentiate particulate matter from bacteria.

11. No one single method has been shown to be completely satisfactory in studying microbial populations.

B. Environmental Aspects

(1) Impact on Hydrology

This section attempts to outline what will happen to the hydrology of the donor and receiver systems from the year 1972 to about 2000.

Without any additional inputs over those already operative, and assuming Wachusett Reservoir will be kept at a reasonable operational level (elevation 380 - 385 feet), Quabbin Reservoir under average inflow conditions and projected demand, will be dry by 1985 (Figure 53). The present volume of Quabbin represents about 50% of maximum capacity. Assuming that a Connecticut River diversion is implemented in 1976, and a Tully diversion by 1980, Quabbin Reservoir will increase in volume for about 20 years and then return to its present volume by 1998. These figures are based on current estimates of projected demands (450 mgd in 1992) and the assumed inputs to the system (see Table 24).[1] Assuming these implementation dates for the two diversions, and the figures as outlined, four distinct time periods during which the volume of water impounded at Quabbin Reservoir will undergo major changes are as follows:

1972 - 1976 (Phase I)	No Connecticut River or Tully System diversion. Quabbin water consists of about 11% Ware River water. Volume steadily declines.
1976 - 1980 (Phase II)	Connecticut River diversion implemented. Volume steadily increases. Ware River diversion represents decreasing proportion while Connecticut River represents an increasing proportion of total volume (Table 25).

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[1] Figures supplied by Construction Division, MDC and U. S. Army Corps of Engineers.

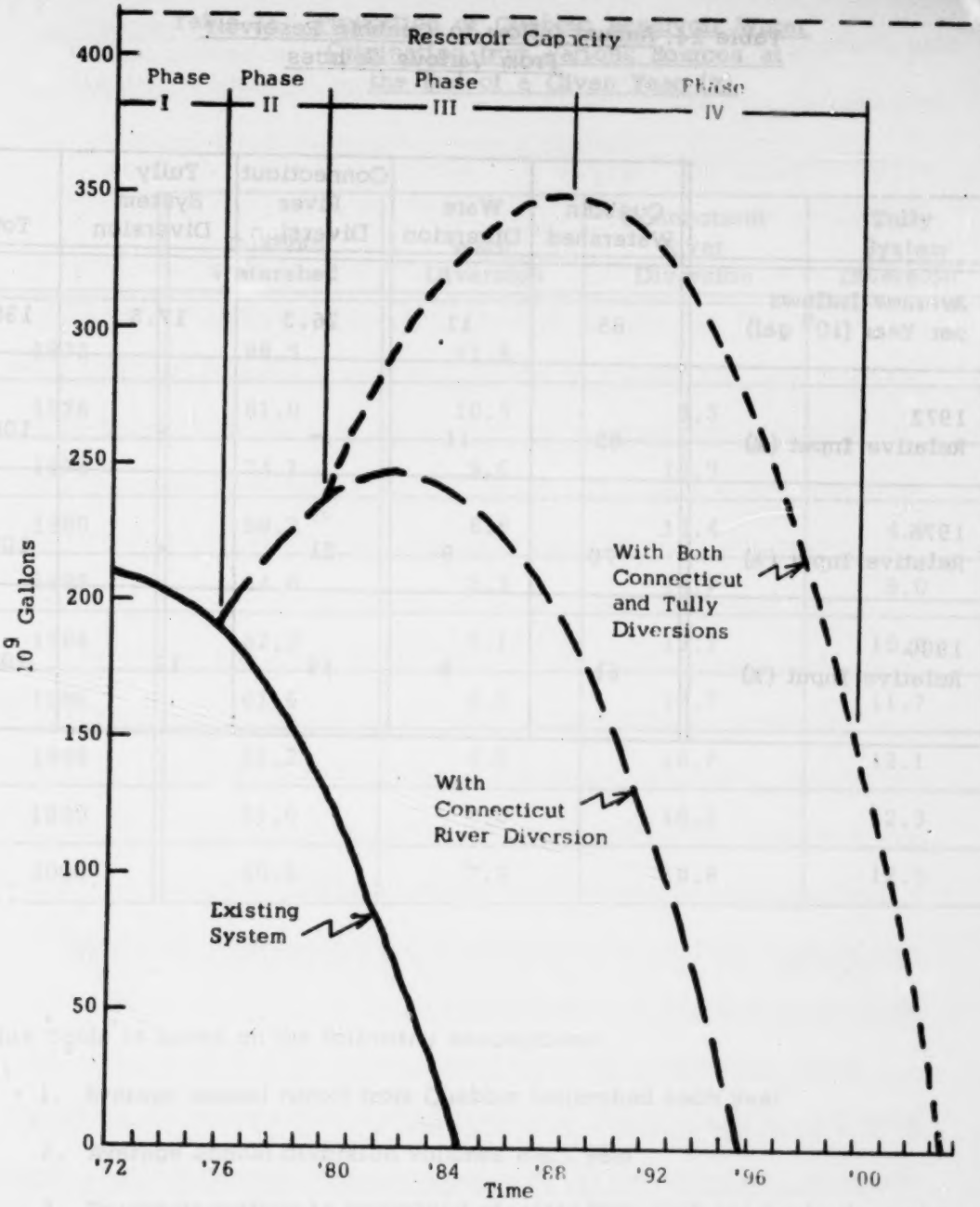

Figure 53. Projected Quabbin Reservoir Volumes With and Without Diversions

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Table 24. Annual Inflow to Quabbin Reservoir From Various Sources

	Quabbin Watershed	Ware Diversion	Connecticut River Diversion	Tully System Diversion	Total
Average Inflows per Year (10^9 gal)	85	11	26.3	17.5	139.8
1972 Relative Input (%)	89	11	-	-	100
1976 Relative Input (%)	70	9	21	-	100
1980 Relative Input (%)	61	8	19	12	100

Table 25. Proportion of Quabbin Reservoir Water Originating from Various Sources at the End of a Given Year (%)

	Quabbin Watershed	Ware Diversion	Connecticut River Diversion	Tully System Diversion
1972	88.5	11.5		
1976	81.0	10.5	8.5	
1978	74.1	9.6	16.3	
1980	68.2	8.8	18.4	4.6
1982	64.0	8.3	18.7	9.0
1984	62.3	8.1	18.7	10.9
1986	61.6	8.0	18.7	11.7
1988	61.2	8.0	18.7	12.1
1990	61.0	8.0	18.7	12.3
2000	60.8	7.9	18.8	12.5

This Table is based on the following assumptions:

1. Average annual runoff from Quabbin watershed each year
2. Average annual diversion volumes each year
3. Reservoir outflow is comprised of water from each source in the same proportion as water in storage from that source is to the entire contents

1980-1989 (Phase III)	Connecticut River and Tully System diversions operative. Volume of Quabbin reaches peak of about 87% of its maximum capacity (Figure 53).
1989-2000 (Phase IV)	Quabbin Reservoir volume steadily declines (Figure 53). Relative proportions of waters originating from various sources becomes stabilized (Table 25).

During the year 1971 the level of Wachusett Reservoir dropped significantly. This was caused by lack of diversion of Quabbin Reservoir water into Wachusett Reservoir for a period of time because of maintenance operations. We assume in this report that the volume of Wachusett Reservoir will be kept at a reasonable working level, because drastic reduction of its volume might impair water quality. Therefore we visualize no impact of the proposed diversions on the hydrology of Wachusett Reservoir.

The impact on the hydrology of the donor systems will be to reduce the peak flows of the rivers during high runoff periods in the spring and sometimes in the autumn. This effect is similar to that produced by a flood control dam. A corollary effect of reducing peak flows, is to reduce the amount of flooded area in the river flood plain downstream and consequently the amount of water recharge of the flood plain aquifers.

During each spring diversion period, about 1-2% of the Connecticut River flow volume will end up in Quabbin Reservoir through the Northfield diversion. An additional 1% will come to Quabbin through the Tully diversions, when they are completed. For the spring of 1971, the theoretical figures

would have been 1.5% had the Northfield diversion been implemented, plus an additional 0.9% by way of the Tully system. These amounts represent 1% of the total annual flow of the Connecticut River at Montague City. No appreciable impact on the hydrology of the Connecticut River and its watershed downstream from the Northfield diversion site is expected. Berger (1971) has estimated that the Northfield diversion to Quabbin would create a stage reduction of 0.2 foot at Montague City. It is thus certain that flooded area and recharge of flood plain aquifers will be reduced and the magnitude of these reductions will be small. Obtaining precise estimates of recharge loss would entail additional study of the flood-plain hydrology.

The Tully and Millers River systems will be affected proportionately more than the Connecticut River, with maximum effects on flows in the river reaches immediately below the diversion sites and at the confluence with the main-stem of the Millers River. Tarbell Brook and Priest Brook diversions will reduce peak flows at South Royalston during diversion days. On a monthly basis, up to 17% of the flow will be diverted. On a daily basis, up to 48% of the normal flow at South Royalston may be lost by diversion during the diversion period. As indicated in Table 26, most months will have some days with no diversion loss at all (minimum reduction = 0) because the control flow requirements cannot be met. During wet years, proportionately more water will be diverted and during dry years, diversion

will be minimal (Table 27).

Further downstream, at the confluence of the Tully and Millers Rivers, diversion effects on flow will be most pronounced. Up to 31% of the monthly flow may be diverted during an average year, and on especially high runoff periods, 50% of the daily flow may be expected (Table 28). The impact of these flow reductions on water quality will be discussed in a subsequent section. Further downstream, the reductions in flow will be proportionately less, as additional tributaries add to the flow.

The impact on recharge of groundwater in the main Millers River valley is expected to be minimal because the steep topography of the valley sides adjacent to the river limits the extent of any aquifers that can be recharged from the river. Thus, although the diversions may significantly lower peak flows during the diversion period, the amount of aquifer recharge loss would be small.

Table 26. Maximum and Minimum Daily Reductions in Flow in Millers River at South Royalston during Three Representative Years Assuming Priest and Tarbell Brooks Diversions.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	PERCENT											
Wet Year (1951)												
Max. %	21	23	38	43	12	0	0	0	0	20	34	23
Min. %	0	0	0	9	0	0	0	0	0	0	0	0
Average Year (1943)												
Max. %	0	17	24	22	22	9	0	0	0	1	8	0
Min. %	0	0	0	0	10	0	0	0	0	0	0	0
Dry Year (1965)												
Max. %	0	0	17	26	7	0	0	0	0	0	0	0
Min. %	0	0	0	0	0	0	0	0	0	0	0	0

Table 27. Monthly Loss in Flow in Millers River at South Royalston Assuming Priest and Tarbell Brooks Diversions for Three Representative Years.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	PERCENT											
Wet Year (1951)	2	7	15	17	2	0	0	0	0	2	16	6
Average Year (1943)	0	5	16	15	17	1	0	0	0	1	9	0
Dry Year (1965)	0	0	1	14	0	0	0	0	0	0	0	0

Table 28. Monthly Reductions in Flow in Millers River, at Confluence of Tully River, Assuming Tully System Diversion for an Average Year.

Month	Average % Reduction in Flow	Maximum Daily % Reduction
Jan	0	0
Feb	9	29
Mar	29	45
Apr	26	39
May	31	42
Jun	2	16
Jul	0	0
Aug	0	0
Sep	0	0
Oct	2	15
Nov	15	50
Dec	0	0

Impoundments to be formed by the construction and operation of the diversions will vary greatly in area and duration of water storage. Tarbell Brook weir will impound during the summer a 28-acre pool with a maximum depth of 9 feet, at the spillway, and much of the area with depths less than 5 feet. Fluctuations in pool elevation will be up to 2 feet above spillway elevation during high flows. Priest Brook dam will be operated as a temporary reservoir, filling only when the combined diversion water from Tarbell and Priest Brooks exceed the 120 cfs pumping capacity at Priest dam. When filled to spillway crest elevation, the pool will cover 400 acres with a maximum depth of 25 feet. Using data from an average year, for example, 1943, the pool would be empty until mid-March, increase to 240 acres by March 31 and then become empty again by mid-April. After being empty for 4 days, it would fill again and fluctuate between 90 and 260 acres during the month of May. After diversion stops on June 2, the pool would empty in 6 days. The pool would remain empty throughout the summer and may fill partially in November for a few days. A wildlife conservation pool will be maintained in the middle of the cleared reservoir area, when the water supply pool is emptied.

Tully Dam will be operated in a manner similar to the operation of Priest Dam, with rapid fluctuations in reservoir area and volume. After June 15, the current plan is to maintain a summer recreational pool of 620

acres (maximum depth of 48 feet) through Labor Day. There would be no diversion during this period because of water-contact sports use of the pool. After Labor Day, the pool would be emptied to its winter level of a nominal nine-foot depth to keep the gates from freezing. Long Pond would also be flooded during high water storage and then return to pond status when the reservoir empties. West Branch Tully River dam would be similar to Tarbell Brook installation. A 13-acre pool would be created and maintained by the overflow weir at the pumping station. Only nominal fluctuations in water depth would occur there.

In summary, the operation of the Priest and Tully dams would cause widely fluctuating pools during March, April and May and sometimes in late autumn. Priest Reservoir would be dry during the summer and Tully Reservoir would have a 620-acre pool during this time. Tarbell Brook and West Branch Tully River would have small pools which would be drained each autumn.

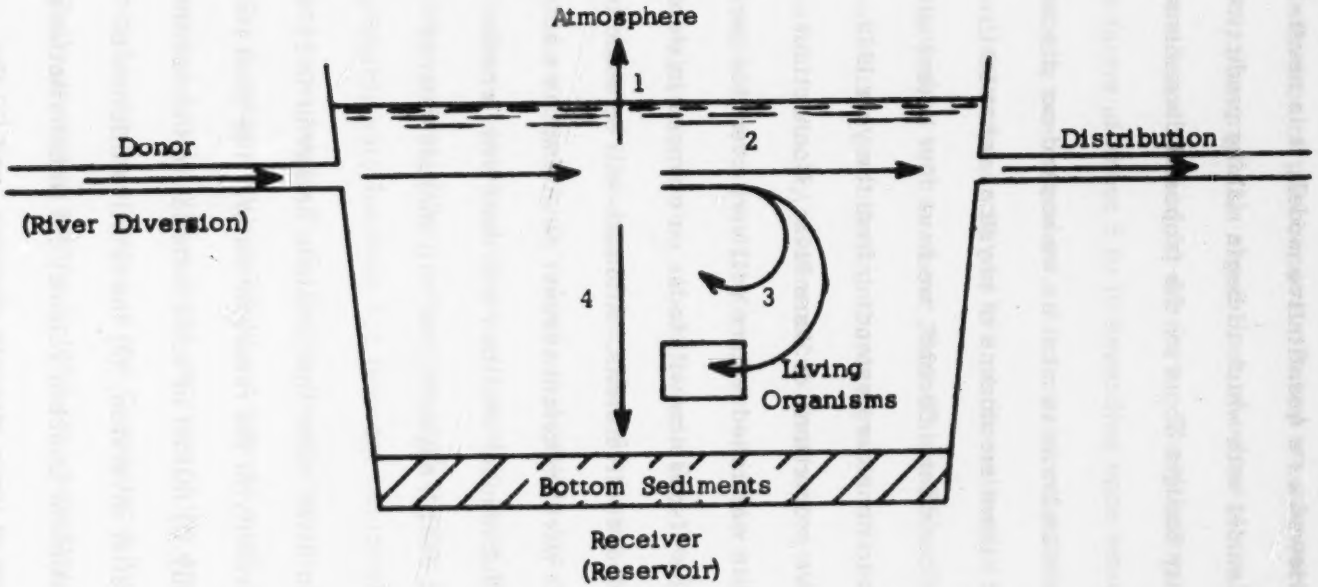
The creation of the impoundments which are a part of the Tully Diversion system may tend to increase groundwater recharge in the Tully area. Although most of the land surface in this region is covered by glacial till deposits, there are glacio-fluvial deposits of sand and gravel adjacent to the several stream channels involved. These deposits are readily receptive to the intake of water and the annual draining of the large pools will help to maintain an unsealed bottom over much of the pool area. The

magnitude of recharge water volume will depend on the extent of the deposits and head of water on them in addition to their permeability. The amount of low flow augmentation resulting from the recharge of these coarse deposits will depend on the proportion of recharge water that penetrates deeply into the underlying faulted gneiss and granite bedrock. There should be some flow augmentation from the surficial deposits during the early part of the summer season.

(2) Impact on Water Quality

Before we undertake a discussion on ecological and public health aspects of the proposed diversions, it would be helpful to analyze the chemical dynamics that underlie the water quality changes in a reservoir as presented in the model in the Introduction (Figure 1).

As water of lower quality is introduced from a donor system into a receiver system, there will most likely be a loss in water quality in the receiver system. This loss of water quality (Figure 1) is due to various materials in the water. These materials include molecules, ions, suspended inorganic materials, organic debris, and living organisms. The fate of these materials is shown in Figure 54. These pathways are not mutually exclusive; for example, a DDT molecule could take all four pathways. What happens to the various materials is a function of many mechanisms. One of the central problems of ecology today is to trace the flow of materials from the various compartments of an ecosystem.



1. Evaporation to atmosphere.
2. Transfer (no change).
3. Transformation, either with or without the involvement of living organisms.
4. Deposition to bottom sediment.

Figure 54. Schematic Diagram of the Possible Fates of Materials Introduced into the Waters of a Receiver System by the Waters of a Donor System.

While our model cannot be viewed as a quantitative model, it is nevertheless a useful qualitative model with which to begin making predictions as to changes in water quality brought about by the proposed diversions, as required by this study.

Several major points must be borne in mind as we expand our discussion on water quality. First, there are dozens of physical, chemical, and biological parameters to consider. Second, we have four hydrologic phases for the entire project to consider, extending from the year 1972 to 2000. Finally, the relative proportions of Ware River, Connecticut River, Tully River and Quabbin watershed waters will vary over this period of years. In this section, the discussion will focus on changes in water quality as a result of the proposed diversions. Attempts will be made to restrict the discussion to the more important issues; no attempt is made to discuss all parameters. Subsequent sections will deal with broader ecological issues and public health aspects, and will include most of the biological parameters.

Diversion of Connecticut River water into Quabbin Reservoir in 1976 will initially increase the turbidity of the reservoir water. The final turbidity will depend upon mainly (1) fallout of some material in Connecticut River water to the sediment after diversion, (2) the relative dilution of Connecticut River water by ambient Quabbin volume, (3) transformations of materials, (4) the influence of ionic strength changes, and (5) the

influence of pH changes. Based on only preliminary data (see Section 7A, paragraph 2), the fallout of material could be significant after a residence time of 60-90 days. The dilution, however, can never exceed a factor of about 5 to 10 depending upon what volumes and how much mixing one considers. Also, water originating in the Connecticut River will be between 18 and 19% of the volume of the entire reservoir during the period 1980 to about 2000 (Table 25). Transformations may change the molecules or colloidal aggregates but will not necessarily cause an elimination. Finally, Connecticut River water will undergo a drop in specific conductance after it enters Quabbin; this will tend to stabilize the colloidal suspensions. If we assume that the Connecticut River will have an average turbidity of less than 25 during freshet flow (Table 23), and that extremely high values are possible but infrequent occurrences, all factors considered above will tend to bring the final turbidity down to a lower value. While we cannot predict what this value will be, it will probably vary between 0.5 (present turbidity) and about 2. Thus, it may not meet future U. S. Public Health Service Standards for drinking water. The turbidity will probably not rise as much during the first two diversion cycles (years 1976 - 1978) because of the smaller relative proportion of total water originating in the Connecticut River (see Table 25). After the Tully diversion begins in 1980, the turbidity will be stabilized at the then

current value, since the turbidity of the Tully system is less, and the percentage of Connecticut River water in the reservoir volume will remain approximately constant (Table 25).

Ions that form insoluble complexes (Mn, Fe, Ca) tend to precipitate out into the sediment if suitable anions are available. Such anions decrease in concentration as the pH becomes more acid, and thus these ions will tend not to precipitate out as the Connecticut River waters mix with Quabbin waters. On the other hand, these ions originating from Tully River waters will tend to precipitate out as the more alkaline conditions of the Quabbin Reservoir are encountered. Thus there is a tendency to balance. However, we cannot predict what the trend will be over a two-decade period, because the exact proportions cannot be predicted and the long-range stability for pH values in all systems is unknown.

There are at least two major concerns on the possible deterioration of water quality that have ecological significance. One concerns oxygen depletion, and the other is the introduction of additional nutrients which can lead to eutrophication.

A comparison of NER data with other available data suggests that COD values for the Connecticut River are about two times as high as for the Quabbin "inside" stations, and are somewhat greater than twice the values for the Quabbin "outside" stations. Reference to STORET data for the past decade shows occasional COD values for the Connecticut River above

50 mg/l. Both the Connecticut River and Quabbin Reservoir waters maintain high 0_2 levels, and during the freshet-flow periods are probably close to saturation. The concern here is an assessment of the potential depletion of 0_2 from Quabbin waters as a result of the proposed diversion.

COD represents a potential 0_2 consumption that is measured using a strong chemical oxidizing agent. Such potential oxidation may never be achieved under field conditions, where biological processes mediate the chemical reactions. Actual oxygen consumption is a function, in part, of the kind of materials that are included in the COD measurement. Organic materials may represent a major portion of the COD when COD's are high and usually exert an oxygen demand through biological processes. Although these organics are all oxidized in measuring COD, some, such as simple sugars, are easily oxidized through biological processes, while others, such as cellulose (a sugar polymer) are relatively resistant to biological oxidation. Depending on the ease with which the material can be oxidized under natural conditions, the full COD may or may not be exerted upon the water.

If most of the COD is in particulate form (which is probably true for the Connecticut River) much of the material with a potential demand for oxygen could settle out either in the Northfield Pumped Storage Reservoir or in upper Quabbin Reservoir after diversion. Although settling reduces the COD of the water column, the potential oxygen demand is conserved

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in the mud. Moreover, the organic component of the sediment may be acted upon by the lacustrine microbial populations at the mud-water interface, and transformed into more easily oxidized compounds. Some materials in the diverted waters may interfere with biological activity in the mud-water interface and either inhibit or enhance the transformation processes. Seasonal turnover and wind effects can stir up these bottom deposits into the water column. These effects are intensified if the reservoir levels decrease. The resuspension of transformed organic muds can serve to deplete available oxygen quickly because COD that had accumulated over many years through the settling process is suddenly present in the water column. If the stirring of the bottom mud never occurs, then COD that is settled out may be buried in the anerobic sector of the mud and may never exert its 0_2 demand on the water.

Included in COD values are the oxygen demands of inorganic materials such as iron and manganese. These inorganic species can have high 0_2 demands if they are in a chemically reduced state. However, in the Connecticut River, laboratory analysis shows that the iron is mainly FeIII and that the manganese may also be already oxidized.

All the above factors make it difficult to predict the impact of diverting Connecticut River waters with a higher COD into Quabbin Reservoir. Localized oxygen-depletion effects have been observed in the eastern arm of the reservoir. It is probable that similar effects will be observed after

diversion in the northern part of the reservoir as well. The impact on the hypolimnion in the deeper part of the reservoir cannot be predicted at this time. Diversion of waters from the Tully system will probably cause relatively less impact, since the COD values are lower. However, this depends on the specific molecules which comprise the COD and comparisons based on COD values alone must be tentative. Oxygen depletion will depend on a complex of biological and chemical processes in these aquatic systems. In conclusion, then, it's very possible that the proposed diversions may result in some localized oxygen depletions in the reservoir. The extent and magnitudes of such depletions cannot be predicted.

The changes in water quality resulting from nutrients introduced from the diversions must also be assessed. Most experts agree that C, N, P and trace materials are important nutrients for algal growth. However, significant levels of C, N, and P already exist in Quabbin, especially in the general area of the proposed diversion discharge (Q-5). Connecticut and Tully Rivers have higher values for N and P in general than Quabbin, but not by large factors. Nutrients are discussed further in subsequent sections. Their importance as far as water quality is concerned lies in the potential for eutrophication.

The presence of phenolic compounds during the third quarter warrants some discussion. Phenols were reported in four riverine stations in the

northern tributaries of the Millers River in concentrations in the order of 1-10 ppb. This is considered an undesirable level for drinking water (FWPCA, 1968). However, several factors must be considered here. First, no odors were detected and secondly, in a spot check the presence of lignins and tannins was found in these waters (see Section 5 B). When the detection method is not sensitive enough, as in this case, it is possible to get a positive indication from any phenolic substances. Also, these test results were for the third quarter after an extensive growth of vegetation, and when color in the water was also high. It is very probable, then, that the phenols reported may not have been simple phenolic materials, but the presence of phenolic groups on more complex molecules.

Referring back to our model (Figure 54), a number of mechanisms can be expected to operate after the diversions of river waters. Much of the larger material will settle out, probably within hours and days. Many transformations can be expected, based on both inorganic and biological reactions. Detergents would be degraded, although no significant MBAS levels were found. As the carbonates from the Connecticut River reach the more acid reservoir waters, equilibria will shift and some $C0_2$ will go off to the atmosphere. Those from the Tully would be retained. However, they are relatively low. Organic materials including the CCE will probably be oxidized. Some NH_3 may also be oxidized, but most of it

would be transformed by the biota. Color would decrease. This loss of color could be at least tenfold, based on evidence from the existing Ware River diversion. Finally, many highly insoluble organic materials, including hydrocarbon pesticides and organomercury compounds would tend to evaporate, as they reach the relatively large surface area of the reservoir.

The general trend will be towards an improvement in quality as the diverted water is retained in the reservoir. Whether the retention time of 60 to 90 days before the Connecticut River and Tully system waters reach the general position near Shaft 12 is sufficient to cause recovery ($\Delta QR = \Delta QL$) is unknown. However, the much longer retention times to reach the Winsor Dam area (See Section 6A) could also allow for some recovery. We can predict, however, that dilution with ambient reservoir volume will not restore the water quality alone. Some "fallout" of materials due to sedimentation, transformation and evaporation must occur to restore quality. The "treatment plant" capacity of the reservoir can probably handle some restoration of water quality. The magnitude of this capacity is now unknown. Because of its capacity to handle waters from the Ware River diversion with efficiency for 30 years of diversion, we may assume it has some reserve capacity. However, assuming that a loss of water quality occurs with some diversions of Connecticut River water (Case II or III, Figure 2), further deterioration will

be checked as Phase III begins.

Before ending this section, several general statements appear useful to tie together our thinking. During Phase I the water quality will deteriorate as the volume in Quabbin Reservoir decreases. This loss of quality could progress to a dangerous point if the volume of hypolimnion waters is drastically reduced. Any losses in quality due to Connecticut River diversion must be judged in the light of water quality loss without diversion. Secondly, the volumes of water represented by Connecticut River origin will be relatively low during the first few diversions. This allows ample time to study the actual impact of diversion during a period of lower potential to cause a negative impact on water quality. Thirdly, the Tully system diversion in increasing total volume (Phase III) should improve the "treatment plant" capacity of the reservoir and thus an improvement in quality may take place. Also, it must be remembered that as the pollution abatement plans are implemented in the 1970's, the quality of riverine waters will improve. Finally, without even further sources of water inflow, Quabbin Reservoir is destined to deteriorate rapidly by the end of the century, because low water levels will interfere with natural treatment processes.

Turning now to the donor systems, diversion of water from any stream or river, which is receiving inputs of nutrients or pollutants downstream from the diversion site, will have the effect of increasing the concentration

of the nutrient or pollutant above what it would have been without the diversion. Berger (1971) has pointed out that the reach of the Connecticut River between Northfield, Massachusetts and Thompsonville, Connecticut receives a disproportionate load of nitrogen and phosphorus. The effect of the proposed diversions would be to increase the concentration of these additional nutrients by 3% at most. Considering, for example, that flood flows now have a 50% lower concentration of both nutrients than do low flows at Thompsonville, the projected increases would not be significant. Indeed, they would be less than normal annual fluctuations in the water.

On similar grounds, other water quality parameters would not change to any significant degree. One might argue that slight reduction in flow volume will reduce the total mechanical erosion of the banks and thus reduce the solid load and turbidity downstream. We view these changes of a few percent, however, to be insignificant, and to leave neither positive nor negative impacts on water quality below the proposed diversion site on the Connecticut River. We add, however, the possibility that retention of Connecticut River water in the upper reservoir of the Northfield pumped storage facility may cause some changes in water quality. However, the impact of these changes in water quality will probably be minor, after the water is returned to the Connecticut River.

Because of the complex of impoundments and the larger relative volumes proposed to be diverted, the impacts on the Millers River

system are potentially greater. Diversion from Priest and Tarbell Brooks would decrease the water quality on the Millers River under present conditions during days of diversion, especially at South Royalston. Diversions from other locations of the Tully System would increase even further any losses in water quality along the mainstem of the Millers River.

During the spring runoff period, paper pulp in suspension was noted at South Royalston and at decreasing concentrations at all other Millers River stations. Apparently, the turbulence associated with high flows can scour some deposits of pulp and carry them downstream, thereby partially cleansing the bottom habitats. Reduction in peak flows would tend to reduce the effectiveness of this cleansing action. However, apparently the existing uncontrolled flows are not adequate to clean the river. It is necessary to stop the input of pulp before this suspended load can be reduced. After the proposed state-federal secondary treatment cleanup of the Millers River, the diversion during spring runoff periods would have only minimal impacts on water quality downstream to the Connecticut River. Thus the short term impact of the proposed diversion will be to decrease water quality downstream, but because of the proposed cleanup, long term impacts should be minimal.

Impoundments present other problems. Shallow ponds, such as those proposed for the tributary streams, tend to reduce the quality of

water impounded in them. Water temperatures are increased, algal populations tend to bloom, and dissolved oxygen depletions occur as the algae blooms decline. The short-term outlook for water quality in the impoundments, is a decline in quality. The long-term (20 year) projection is definitely toward lower water quality from the impoundment areas.

In general, the longer the retention time, the greater the probability of ecological changes towards the lentic condition. Although specific changes in the ecology of a single impoundment are difficult to predict, it is reasonable to assume that the ecological changes in the impoundments at Tarbell Brook and the West Branch of the Tully River will progress more closely towards a relatively stable lentic condition than will those at Priest Brook, for example. Thus we visualize a whole range of ecological changes in the impoundments.

(3) Impacts on Ecology

There can be little doubt that increased levels of nutrient chemicals will be detected in Quabbin Reservoir after the implementation of the Connecticut River diversion and before the implementation of the Tully system diversion. However, not all nutrients can be expected to show such an increase in this time period. Phosphorus increases are possible, but not probable. Increases in available carbon, on the other hand,

are quite probable, if only due to the relatively high alkalinity of the Connecticut River. Also, the fact that fecal contamination of the Connecticut River does occur increases the likelihood that complex organic molecules will be introduced into Quabbin and possibly into Wachusett where they will become part of the nutrient pool. The future abatement of pollution in the Connecticut River will contribute significantly to the lowering of any such nutrient addition to the reservoir through diversion.

It is important to note that current nitrogen, phosphorus, and carbon levels in Quabbin are sufficient to support larger phytoplanktonic populations than presently exist. Increased levels of these nutrients do not necessarily mean, then, that higher concentrations of algae in Quabbin can be expected as a direct result of the diversion. It is quite possible, however, since nitrogen, phosphorus and carbon appear not now to be limiting, that the Connecticut River diversion may increase the levels in Quabbin Reservoir of some now unknown limiting growth factor, such as a vitamin. The importance of this possibility cannot be overemphasized. Additional studies on limiting growth factors in both Quabbin Reservoir and Connecticut River waters are required (see Section 10, Recommendation No. 2).

Finally, we cannot overlook physical factors such as water temperature as possible limiting factors in algal growth. For example, not all algae have the same optimum growth temperature. Therefore, any

differences in temperature between donor and receiver systems could influence numbers and types of algae in the final water mass. A relatively cooler water mass from the Connecticut River might suppress the growth of some species of blue-green algae. This could however, also augment the growth of other species. Not enough is known about the growth requirements of the algae in question to permit meaningful predictions. Any increases in nutrient levels in Quabbin waters due to the Connecticut River diversion will most likely tend to be lessened by the diversion of the Tully system.

There is no reason to believe that undesirable algal species will be introduced into Quabbin Reservoir by either diversion. Any changes in the current algal populations in Quabbin will most likely be the result of the response of present populations in Quabbin to changing levels and kinds of nutrients brought about by the diversions.

The proposed diversion of Connecticut River waters into Quabbin Reservoir stands a good possibility of having an ecological impact upon the fisheries of Quabbin. Furthermore, in view of the position of the Massachusetts Division of Fisheries and Game, the impact would be a negative impact. We must assume that undesirable species will be introduced into Quabbin Reservoir if Connecticut River waters are diverted into Quabbin.

Experience with the present Ware River diversion into Quabbin Reservoir does not provide any insight into this problem. Fish species in

the Ware River and Swift River watershed and hence Quabbin are about the same. There is no evidence of carp or eels in the Ware River (personal communications, Massachusetts Division of Fisheries and Game). Thus we cannot refine our estimates on the impacts on fisheries from experience with the Ware River diversion. The consequences of introducing undesirable species could be felt in several ways. First, the present ecological balance between species will be lost. Secondly, if the salmonid population is decimated by undesirable species competition, and a warm water fish population predominates there is good likelihood that the number of angler trips by sports fishermen to Quabbin Reservoir will decline. This in turn will reduce the harvest and further influence ecological balance. The issue, then, is not a reduction of the standing crop of total fishes in Quabbin Reservoir, but the disruption of the present success in the management of a salmonid fisheries program.

Since the species representation in Quabbin Reservoir is similar to that of the Tully System, the proposed diversion of the waters of the Tully into Quabbin will not have any significant effect on the fisheries in Quabbin Reservoir.

When presented with a request for recommendations for fish exclusion measures, the Division of Fisheries and Game presented the following alternatives.

a) A fine mesh traveling screen,

b) An electrical barrier utilizing a low-gradient voltage pulsating DC current, backed up by a fine mesh traveling screen,

c) Chemical treatment through chlorination at a high rate to kill eggs, larvae and juvenile fish, and facilities to dissipate chlorine prior to diverted water entering the reservoir.

These alternatives must be designed to function with the proposed flow rates. No detailed specifications for the alternatives are presented. Before a decision is made, the Division feels that further studies to determine the rate of chlorination necessary to kill eggs, larvae and juvenile fish are necessary. However, the reactions of chlorine with organic material dissolved and/or suspended in the diverted waters will also produce chloramines which may adversely affect benthic populations in Quabbin Reservoir which are part of the fisheries food chain. This impact cannot now be precisely defined. Continuous monitoring of fish populations over long periods of time will be required for any further elucidation of the likelihood and magnitude of this problem.

Increased concentrations of organic molecules in Quabbin as a result of both the Connecticut River and Tully system diversions may affect the dissolved oxygen content of Quabbin waters due to the oxygen demand of these molecules as discussed earlier. The magnitude of any overall decrease in oxygen in the hypolimnion and the epilimnion of the Quabbin

Reservoir, however, cannot be predicted. Localized depletions of oxygen in Quabbin Reservoir have been periodically noted over the past half dozen years as a result of the present Ware River diversion. These depletions have been observed only in the southern part of the eastern arm of Quabbin, and have been short lived. The proposed diversions may be expected to produce similar, localized phenomena. The salmonid fisheries in Quabbin are not expected to be affected by any lowering of dissolved oxygen in the upper portion of the middle arm and in the eastern arm of the reservoir. Salmonid fishes are typically found in the main body of Quabbin Reservoir.

Because of the number of factors governing the disposition of pesticides in surface waters (see Section 8A), it is not surprising that only small traces of pesticides were detected in this project. Similar findings are seen in the STORET retrieval data on the Connecticut River (STORET Retrieval Date 69/06/27). Analyses for aldrin, BHC, DDT, dieldrin, endrin and other pesticides during the 1960's show little or no residues in the water. Finally, the findings of Lichtenberg et al, (1970) in a 5-year summary of pesticides in surface waters of the United States report only trace amounts (< 0.1 ppb) of pesticides in the Connecticut River.

A prediction with some certainty can be made about the ecological effects of pesticides in the proposed diversions. The Massachusetts Division of Fisheries and Game has supplied us with data that indicate significant levels of DDT, endrin, dieldrin and PCBs in the tissues of

lake trout taken from Quabbin Reservoir. These pesticides in lake trout reflect the expected concentrations by the food chain if traces of pesticides are already available in the reservoir ecosystem. Nor were the residues of DDT in fish from the Connecticut River (Lyman et al., 1968) any higher than those reported for the fish in Quabbin Reservoir. While more extensive monitoring of the waters, muds, and biota of both the Connecticut River and Quabbin Reservoir for pesticides would increase the certainty of our prediction, we feel that it is highly improbable that the proposed diversion will have any important environmental effects. Similar reasoning can be applied to the proposed Tully System diversion.

Somewhat different from the above impacts is the much more general question of ecological balance. This question cannot be answered in any but very general terms. That any change in an ongoing ecological system is effected and becomes persistent is good indication that a shift in ecological balance has been achieved. The probabilities of some of the more important, possible changes in Quabbin due to the proposed diversions have been discussed above. However, what all the effects of any shift in ecological balance may actually be cannot now be predicted. For example, an increase in Quabbin of "trash fish" populations may result from slight shifts in competition patterns which in turn may result from the introduction of species into Quabbin by the

Connecticut River diversion. The salmonid population could remain essentially unaffected. However, the number of angling trips to Quabbin may very well decline. The harvest of fish would then be lowered and could conceivably be lowered to such an extent that a second shift in the ecological balance would be realized. This second shift, or any subsequest shift, might in turn directly affect the salmonid population. This is a good example of how sociological and biological events can interact to produce a series of complex phenomena which cannot be predicted in any but the most general form.

Similarly the impacts of the proposed diversions into Quabbin or Wachusett Reservoirs are impossible to discuss in any but very general terms until such a time as the specific impacts discussed above can be more fully defined by future studies. On the basis of current data, we believe that the possibility of a degeneration in turbidity in Wachusett deserves some mention due to the importance of turbidity in any contemplated future treatment of Wachusett waters prior to their final distribution to consumers. This will be discussed in Section 8 C.

We predict no significant impacts on the general ecology of the mainstem Connecticut River as a result of the proposed diversions. Losses in flow volume and shifts in water quality will be so minor that it is difficult to envision any significant changes in bacterial, algal and benthic

populations. Similarly, no major changes in the existing fish populations, or in the future anadromous fish program are expected.

On the other hand, specific impacts on the ecology of the Millers River system are probable. The impoundment of waters from the northern tributaries will cause changes in the algal and heterotrophic bacterial populations. While the probability that these changes will occur is good, the details cannot be predicted. Eutrophication and algal blooms will increase over the years, and thus offer a long term (over 20 years) impact. Changes in benthic populations in the mainstem Millers River will be slight, except for a possible increase in the benthic fauna characteristic of poor quality water at Station No. 4 (South Royalston). This, however, will be a short term impact, and will reverse itself after the Millers River is cleaned up under the proposed state-federal abatement plans. The impoundments will result in gradual changes in both benthic fauna and fish populations, as they change from lotic to lentic environments. These changes will be influenced by drawdown and other dynamic changes in the hydrology. Tributaries will experience minor changes in general ecology. Consistent with previous statements, changes in the ecology in impoundments are more probable in Tarbell Brook and the West Branch of the Tully.

Finally, little detailed information on the construction phase of the proposed diversions has been available for study. Therefore, the impact

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of this phase on donor and receiver systems has not been discussed in this report. However, both the MDC and the Corps of Engineers are well aware of the importance of this phase to any understanding of the overall environmental impact of the proposed diversions.

C. Public Health Aspects

Coliform bacteria are indicators of possible human fecal contamination and therefore of the possible presence of human pathogens, including bacteria and viruses. Coliform bacteria are not themselves, however, pathogenic. It is reasonable to assume that concentrations of coliforms will increase in Quabbin Reservoir as a direct result of the Connecticut River diversion. Therefore the possibility of finding agents of human infection in the area of Shaft 12 in Quabbin will also be increased by the diversion. The measure of real risks to public health associated with this possibility is, however, a function of a number of other variables. These variables include the general health of populations contributing to the fecal pollution of the Connecticut River, treatment of water before its entry into Quabbin, residence time of this water in Quabbin, dilution of diverted waters by Quabbin waters; and finally, treatment prior to final distribution.

While the MDC is currently planning, according to a Massachusetts Department of Public Health directive, to chlorinate diverted waters prior to their entry into Quabbin, we feel that the varying turbidities of these waters, and the resultant inefficiencies of chlorination, ensure the possibility that pathogens imbedded within suspended debris will find their way into Quabbin. Chlorination of diverted waters prior to entry into Quabbin will probably be less important a means of controlling the introduction of these pathogens than will the implementation of present

pollution abatement plans for the Connecticut River.

Even with the implementation of present abatement plans an important question is how long diverted waters can be expected to remain in Quabbin. In general, the natural purification processes of a lake will reduce the coliform concentrations in proportion to the length of time these bacteria are in residence in the lake. The die-off rates of coliform bacteria are generally considered to be similar to die-off rates of pathogens. While recent research indicates that there is not necessarily a direct correlation between the die-off rates of coliform bacteria and pathogens, it is generally assumed that residence times of several weeks provide reasonable disinfection (Fair, Geyer, and Okun, 1968).

Our model studies thus far indicate that diverted waters will have reached the general area of Shaft 12 within 2-3 months of the time they are introduced into Quabbin. Portions of these waters will be mixed with waters derived from the southerly portions of the main body of the reservoir as they are taken into Shaft 12; other portions will continue in a southward flow to mix eventually with the waters in the western arm. While it can be expected that significant die-offs of pathogens will occur within a 2-3 month residence in Quabbin, and that maximum dilutions of diverted waters will probably be realized within one diversion cycle, the possibility that some pathogens may find their way into the Quabbin aqueduct has to be assumed. The possibility that some pathogens will find their way into the Chicopee outlet at Winsor Dam also has to be assumed; however, because preliminary laboratory model studies indicate it will take about 7 months for diverted waters to reach Winsor Dam, and because of the greater dilution of these waters

which would then have taken place, the probability of detecting pathogens at the Chicopee aqueduct would be lower than that of detecting them at the Quabbin - Wachusett aqueduct.

Because model studies to date have not taken into account the effect of winds on residence times of diverted waters, and because pertinent information of the die-away phenomenon is by no means complete, it is not now possible to predict the actual number of pathogenic organisms which may possibly find their way into the Quabbin-Wachusett and Chicopee aqueducts as a result of the Connecticut River diversion. Average times in days for a 99.9% reduction of enteric organisms, reported by Fair, Geyer, and Okun (1968) range from 10 (for Coxsackie A9 virus in Little Miami River) to 130 for Echo 7 virus in sewage). These rates are published with the provision, however, that they are useful only for similar conditions of test.

Because coliform concentrations within the Tully System are comparable with the minimal concentrations already observed in Quabbin, and because current model studies indicate that the residence time for Connecticut River diversions in Quabbin will not be reduced appreciably by the Tully System diversion, the impact of the Tully System diversion will be to reduce further any public health hazard associated with the Connecticut River diversion.

It is important to note that any pathogens which do find their way into the Quabbin-Wachusett aqueduct will be subjected to dilution by Wachusett waters as well as to the self-purification processes of that reservoir. Given the dilutions and residence times of diverted waters in both reservoirs, we conclude that while the introduction of pathogens into Wachusett Reservoir is possible, it is improbable

that they will be detected in Wachusett. Finally, any enteric organisms which may be present in Wachusett as a direct result of the contemplated diversion may be easily destroyed by existing or contemplated chlorination within the distribution system.

The presence of mercury at all sampling sites suggests that it is reasonable to assume that mercury is a component of the waters of this region. While the levels are generally low and thus pose no immediate hazards, the possibility of significant concentrations in the food chain must be assumed. Indeed, data from the Massachusetts Division of Fisheries and Game indicate levels of mercury in fish taken from Quabbin Reservoir to be in the range of 10^2 - 10^3 ppb, in this regard being similar to levels found in fish in the Connecticut River. Several peak values for mercury in excess of 5 ppb have been found in some locations, including the Millers River and Quabbin and Wachusett Reservoirs. Most of these values occurred earlier in the year, and recent data indicate lower values. The reasons for these values are unknown, nor can the present study, due to the sampling situation, define any possible sources. This would require a separate study in itself. Our conclusions on the impacts of the proposed diversions, however, must be based on comparative data for the proposed donor and receiver systems. On the basis of the data, we must conclude that no public health hazards due to higher levels of mercury can be expected from the proposed diversions. Indeed, the data suggest that lower levels in water exist in the proposed donor systems.

Because of the number of factors governing the disposition of pesticides in surface waters (see Section 8 A), it is not surprising that only small traces of pesticides were detected in this project. Similar findings are seen in the STORET

Retrieval Date 69/06/27). Analyses for aldrin, BHC, DDT, dieldrin, endrin and other pesticides during the 1960s show little or no residues in the water. Finally, the findings of Lichtenberg et al. (1970) in a 5-year summary of pesticides in surface waters of the United States report only trace amounts (< 0.1 ppb) of pesticides in the Connecticut River.

Pesticide information was reviewed in earlier sections. The findings confirm the position that the Connecticut River waters would not present a public health hazard if diverted into Quabbin Reservoir. In the first place the amounts of pesticides are too low, and secondly the evidence indicates trace amounts to be present in Quabbin Reservoir already. Therefore, the proposed diversion would not introduce pesticides into a reservoir that was already free from such compounds before the diversion.

Our data on radioactivity, and recent information from the Lawrence Experiment Station of the Massachusetts Department of Public Health (Donlon, personal communication) leads us to conclude that no public health hazards will result from the diversions of Connecticut River waters or Tully System waters into Quabbin Reservoir. The Lawrence Experiment Station has been testing Connecticut River water as part of the cooperative efforts of the Tri-State Commission for some time, and has detected neither ^{226}Ra nor ^{90}Sr in the water. Also surface waters, including reservoirs, from all over Massachusetts have been treated in the spring and fall, and no presence of ^{226}Ra or ^{90}Sr has been detected. On the other hand, some of the STORET Data (Retrieval Date 69/02/27)

for 1960s show Connecticut River water with total beta activity in excess of 10 μμc/liter. This is not true for the more recent data. These discrepancies are common for Connecticut River data, and point out the need for continual monitoring. Such continual monitoring is also desirable in view of the future operation of a nuclear power plant at Vernon, Vermont. We affirm our conclusion, however, that in view of existing guidelines, we see no immediate or long-range public health hazards from radioactivity in the donor systems.

The risks to human health which are inherent in the consumption of any surface waters cannot, of course, be completely eradicated. However, given man's past experience with public water supplies and his present technology, we conclude that those risks which can be associated with the proposed diversion are reasonably comparable with those generally taken in the consumption of Massachusetts surface waters.

Based on available evidence, there is no reason to anticipate any public health hazards to the donor systems resulting from the proposed diversions. A positive impact on the Millers River system is possible, the main reason coming from the probable decrease in any pathogens as a result of the impoundments. Impoundment of water results in a decrease in pathogens, due to die-off. However, while coliform bacteria are present in these waters, we have no direct evidence of any pathogenic organisms.

D. No-Diversion Alternative

Within the intent of the National Environmental Policy Act of 1969, we

should also consider the alternative of no diversion. Mention has already been made of the probable deterioration in water quality in Quabbin Reservoir during Phase I. Extending our time reference beyond 1976, we predict a further deterioration in the condition of Quabbin Reservoir if the projections as shown in Figure 53 are operative. Central to these projections are average inflow conditions and the realization of the projected increases in water supply demand.

An analysis of the dilemma can be approached in terms of classical limnological concepts. Under full pool conditions, Quabbin Reservoir would resemble a temperate lake of the second order (Welch, 1952). Moreover, the condition would be quite characteristic of an oligotrophic lake. In such a lake nutrients are low, electrolytes are low, dissolved oxygen levels are high, algal blooms are rare, and cold-water fishes (salmon, trout) are found in abundance. As the reservoir loses volume, it will approach the conditions of a temperate lake of the third order, the chief characteristic of which is a loss of thermocline and the development of essentially isothermous conditions. Such a lake will move faster toward a eutrophic condition than will a second order lake. Eutrophic lakes are relatively shallow, nutrients are abundant, dissolved oxygen may be absent in deeper layers, blooms are common, and the fish populations are predominantly warm-water fishes (Welch, 1952).

However, the situation at Quabbin Reservoir is complex in that some sections are very deep (over 100 feet), whereas some areas of the northern section are very shallow. Moreover, the reservoir is a dynamic and not a static pool, with

substantial, annual inflow-outflow volumes. Therefore, it is very difficult to state at what elevation (or volume) the reservoir will reach a "critical point". Water quality conditions, algal growth patterns, and fishes in the northern sections suggest that progression toward eutrophication is already taking place there. Water quality in the main body is still of a high quality. As the projected volumes decrease over the years, the relative masses of high versus low quality water will shift toward an overall loss in water quality. Losses in volume will decrease the treatment capacity and possibly the retention times of new inflow waters. Losses in hypolimnion volume will certainly diminish the standing crop of salmonid fishes. Finally, at some point in time before total water depletion (1985), Quabbin Reservoir will not be acceptable as a public water supply. Our conclusion, therefore,is to regard the no-diversion alternative as unrealistic unless other alternatives, outside the scope of the present project, offer better solutions to the projected Boston metropolitan water supply problem.

E. Delays in Diversion

Related to the no-diversion alternative is the concept of delays in diverting the proposed riverine sources. Again, we cannot set a critical time limit, after which diversion of riverine waters might pose a higher risk to the maintenance of a good water supply. Several seasons with good inflow into Quabbin Reservoir, such as with the current situation in the spring of 1972, would displace the curve "existing system" of Figure 53 to the right. Another drought period would shift it to the left. Assuming again, as we did earlier, that the supply and demand

remains as projected, about half of the current volume of Quabbin Reservoir will remain by the end of this decade. As a first approximation, we are guessing that the relative decrease in water quality, the marked decrease in diluting volume, the reductions in retention time and the reductions in treatment capacity will increase the risks of diversion if diversion is delayed by four years to 1980. If on the other hand the water quality of Quabbin Reservoir decreases faster than we believe during this period of delayed diversion and if the Connecticut River waters improve faster than projected through abatement procedures, we could indeed be faced with a reversed situation, in which the riverine waters are of a higher quality than those of the then-existing reservoir. Irrespective of the exact year, at some point in time, riverine waters will actually be of a higher quality than the reservoir. Under these conditions, it is impossible to predict the final water quality after diversion and retention of Connecticut River water in the then-existing reservoir. We can predict, however, that the maintenance of a good water supply will be greatly impaired following significant delays in the proposed diversions.

9. SUMMARY

This study was a cooperative effort of several organizations to generate and evaluate extensive data on the Quabbin and Wachusett Reservoirs and the Connecticut and Millers Rivers systems, with the objective of making predictions on the impacts of diverting portions of these riverine systems into Quabbin Reservoir.

Field and laboratory data included approximately 100 parameters, including chemical, physical, biological, and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information, and pollution abatement plans were considered and evaluated. Finally, other pertinent data available from both public and private sources, especially on the Connecticut River, were evaluated in the light of the objectives of this study.

Central to the evaluation was the development of a qualitative model of reservoir dynamics. Such events as evaporation, sedimentation, transformations, and direct transfer of materials from potential donor to receiver and finally to the distribution system were discussed. Any predictions on water quality as a result of diversions were qualified by our present knowledge of the underlying dynamics.

Dilution of riverine waters by ambient reservoir volume alone will probably not be sufficient to insure an acceptable water quality in Quabbin Reservoir. Fallout of suspended materials and the "treatment plant" capacity of Quabbin Reservoir are expected to result in an acceptable water quality.

A general summary of the impacts of the proposed diversions on Quabbin

Reservoir is shown in Table 29. The potential magnitude of a given impact upon Quabbin Reservoir is generally higher with the proposed Connecticut River diversion than with the proposed Tully River system diversion. Predictions on the temporal aspects of any impacts cannot be made at this time.

As a convenience in making evaluations of the probable impacts of the proposed diversions, the period 1972-2000 was divided into four phases. Phase I (1972-1976) is the period before diversion of the Connecticut River. The volume of Quabbin Reservoir will decline during this period. Phase II (1976-1980) represents the period for the beginning of the Connecticut River diversion; the Tully River diversion is not yet operative. The reservoir volume will increase during this period. The period 1980-1989 (Phase III) represents a period when both diversions are operative, and the reservoir volume continues to increase. During the final phase (Phase IV, 1989-2000) both diversions continue to be operative but reservoir volume declines. Probable, major long-term trends in Quabbin Reservoir for this overall period are summarized in Table 30.

The greatest potential for both ecological and public health impacts on Quabbin Reservoir is seen to exist with Phase II. Because of declining reservoir volumes, Phases I and IV will show some deterioration of the reservoir.

Impacts of the proposed diversions on the two donor systems will differ. We expect no significant changes in the hydrology, water quality or general ecology of the mainstem Connecticut River. Temporary storage of Connecticut River water in the upper reservoir of the Northfield pumped storage facility may

Table 29. Summary of Probable Impacts of the Proposed Diversions on Quabbin Reservoir

Note: This summary does not predict the duration of the impact.

Description of Impact	Relative Probability Impact Will Occur			
	No significant change over existing conditions	Possible but Probability Low	Probable	Probability High
Increase in Nutrient Chemicals		T	C	
Increase in Eutrophication		T	C	
Modification of Present Equilibration			C T	
Introduction of Undesirable Species		T		C
Increase in Coliform Bacteria		T	C	
Increase in Human Pathogens		C T		
Interference with Water Treatment at Quabbin		T	C	
Increase in Levels of Toxic Materials	T	C		
Increase in Levels of Radioactivity	C T			
Increase in Levels of Pesticides	C T			
Increase in extent and magnitude of oxygen depletion		T	C	

C = Connecticut River Diversion T = Tully System Diversion

Table 30. Probable Major Long-Term Trends in Quabbin Reservoir

Phase	Trend
I (1972-1976)	Progressive deterioration of northern part of middle branch, and the eastern branch.
II (1976-1980)	Shift in ecological balance, especially middle branch. Water quality changes probable. Volume increase may actually retard some deterioration from Phase I. Potential public health hazard greater than Phase I.
III (1980-1989)	Probable improvement in water quality. Further reduction in deterioration in northern part of middle branch begun in Phase I. Potential public health hazard reduced over Phase II.
IV (1989-2000)	Progressive deterioration of entire reservoir.

cause some changes in water quality. However, the impacts of these changes after diversion to the receiver or return to the donor will probably be minor. In the Millers River system we envision probable changes in the hydrology, in general water quality and in the ecology. These changes will be a consequence of the diversion of relatively large volumes of higher quality water and the impoundment of waters. Because of the proposed cleaning up of the Millers River, changes in water quality in the mainstem Millers River will not be a long term impact. Changes associated with the impoundments will have both long term and short term impacts. There will be no significant public health impacts on the donor systems. Tables 31 and 32 summarize the probable impacts of the proposed diversions on the donor systems.

Realistic appraisal of a no-diversion alternative is also important for this project. Under average inflow conditions and projected demand, Quabbin Reservoir will be dry by 1985. At some time before this year, water quality will decrease, eutrophication will increase, and fish populations will change. Also at some point before total water depletion in 1985, the reservoir will not be an acceptable public water supply. As a related problem, the losses in volume and water quality of Quabbin water will increase the risks of diversion if a diversion is delayed by only a few years. We conclude that the no-diversion alternative is unrealistic unless other alternatives, outside the scope of the present project, offer better solutions to the projected Boston metropolitan water supply problem.

Table 31. Summary of Probable Impacts of the Proposed Diversions on the Connecticut River

Description of Impact	Relative Probability Impact will Occur			
	No significant change over existing conditions	Possible but Probability Low	Probable	Probability High
Significant Changes in Hydrology	X			
Loss of Groundwater Recharge	X			
Changes in Bacterial Populations	X			
Changes in Benthic Organisms	X			
Changes in Fish Populations	X			
Significant changes in Water Quality	X			

TABLE 32. Summary of Probable Impacts of the Proposed Diversions on the Millers River System

Description of Impact	Relative Probability Impact Will Occur			
	No significant change over existing conditions	Possible but probability low	Probable	Probability High
Significant changes in Hydrology			M	I T
Changes in Ground-water Recharge		M (Decrease) T (Decrease)	I (Increase)	
Decrease in Pathogens (if present)		M T	I	
Changes in Heterotrophic Bacteria[1]		M T		I
Changes in Algal Populations[1]		M T		I (Increase in number and change in type)
Changes in Benthic Organisms[1]	T	M (short term)	I[2]	
Changes in Native Fish Populations[1]	M T		I[2]	
Decrease in Water Quality		T	I (short M term)	I (Long term[2])

I = Impoundments on tributaries
T = Tributaries below diversion point
M = Mainstem of Millers River

1 Specific quantitative changes impossible to predict, except where noted

2 Refers primarily to Tarbell Brook and West Branch of Tully River

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10. RECOMMENDATIONS

In a recent letter to the editor of Science, Alvin M. Weinberg (1971) of Oak Ridge National Laboratory, states that scientists "must admit that some questions, including the most important ones raised by concern for the environment, are really trans-scientific, not scientific". Disagreements among scientists concerned with environmental impacts of human actions are usually over these trans-scientific, not scientific, questions, and are therefore not resolvable by science. The basis of such disagreements is usually the question of the validity of the extrapolation of data collected in one set of circumstances to other and different situations.

We believe that the diversion of freshet flows as a means of supplementing dwindling public water supplies is destined to increase in importance in this country, and that disagreements among scientists as to just what the impacts of these diversions will be also will increase. Furthermore, such disagreements will increase in direct proportion to the degree that the issue of freshet flow diversions remains in the trans-scientific domain. Should the frequency of these disagreements continue to increase, the value of science and scientists to those responsible for making decisions of public import will necessarily diminish. This would be inconsistent with the intent of the National Environmental Policy Act of 1969 and other major legislation concerned with environmental quality.

Perhaps the most direct way of insuring that the question of the environmental impact of diversion will become more firmly based on scientific facts as opposed to trans-scientific rhetoric is to work toward the construction of quantitative models

which can take the place of such qualitative models as contained within this report.

The following recommendations are, therefore, predicated by the view that the current studies were only a first attempt to come to grips with the question of impact of the proposed diversions on Quabbin and Wachusett Reservoirs. They are, in short, recommendations for future research which we think is necessary for the realization of a more complete scientific understanding of data already collected, and to improve the model.

(1) Initiate diurnal studies at Quabbin Reservoir. Parameters measured should provide rates of turnover of important algal nutrients, and provide additional information on ecological relationships which may govern those rates.

(2) Initiate algal potential growth studies using water samples taken from both donor and receiver systems. These studies should yield further information on limiting algal nutrients in these waters and on maximum concentrations of algal species which might be expected under given nutrient conditions.

(3) Initiate studies of the nutritional significance of heterotrophic bacteria in both donor and receiver systems. These studies should provide further information on the rates of nutrient turnover in Quabbin Reservoir, before and after diversion, which may be primarily influenced by the capacity of these organisms to degrade organic material.

(4) Initiate studies on the diagenesis of the eastern arm of Quabbin, including analyses of the remains of organisms deposited in the sediment, in an attempt to define "fallout" rates and other changes in water quality in Quabbin which may be associated with the present diversion of Ware River waters.

(5) Initiate chemical analyses of mud samples from Quabbin in order to measure the nutrient potential of the reservoir and to gain some insight into chemical and biological processes occurring at the mud-water interface.

(6) Continue studies on current physical model of Quabbin which will include the conditions of winds and thermal stratification.

(7) Continue a general monitoring program on both the receiver and donor systems so that the development of quantitative models will be continually up-to-date. This is especially true for waters of the Connecticut River and the northern part of Quabbin Reservoir, and the Northfield Mountain Impoundment.

(8) Conduct settling studies on waters collected from both donor and receiver systems in an attempt to define the rate of "fallout" of suspended materials in Quabbin Reservoir after diversion and under different circumstances of diversion.

(9) Computerize all data generated and considered in this report so that cross correlations of these data and other national data may be more precisely examined.

(10) Consider any other studies which might increase an understanding of all dynamic processes in the reservoir, and which are aimed specifically at increasing the predictive capability of the model.

These and other recommendations for future research have been discussed with both the MDC and Corps of Engineers, and are under active consideration. Priorities for each of these recommendations will be decided in conference with these agencies.

APPENDICES

APPENDIX 1

METHODS FOR FIELD AND LABORATORY STUDIES

A. Field Methods

(1) Collection of Surface Waters

Surface waters refers to water obtained from about the first one-half meter in depth. For most surface "grab samples", no special device was used. The appropriate container was held underwater by hand at the desired depth. Glass Winkler bottles were used to collect samples for dissolved oxygen analyses. Glass jugs with teflon-lined caps were used to collect water for pesticide analyses. Polyethylene bottles and jugs of various sizes were used for the collection of waters for other analyses. The usual care to avoid bubbling of air was exercised in the collection of water for dissolved oxygen tests. Manganese sulfate and alkali-iodide-azide reagents were added to the dissolved oxygen bottles in the field.

(2) Depth Sampling Techniques

Depth sampling techniques were necessary for collecting water at depths greater than one-half meter, or for sampling from bridges, embankments or in other instances where the hand was not immersed into the water. A Van Dorn sampler was used to obtain water samples for all analytical tests except for pesticides or bacteriological samples. A prototype harness and weight assembly was built to house the jugs for collecting deeper waters for pesticide analyses.

(3) Collection of Waters for Bacteriological Tests

Unlike the collection for other analyses, collection of water for bacteriological analyses was carried out with sterile, evacuated bottles using a J-Z sampler. Use of the J-Z sampler equipped with a messenger will permit the sampling of both surface and deeper waters.

(4) Collection of Zooplankton

Zooplankton were collected with a Wisconsin plankton net equipped with a number 20 mesh net. The removable bucket of the plankton net was equipped with number 25 mesh. At all deep stations the net was lowered about 10 meters and then pulled straight up at approximately 1 meter per second. The 12-cm diameter and 10-meter high water column resulted in a plankton haul of about 113 liters of water. For surface waters of reservoirs and rivers, a plastic bucket filled to a measured 12-liter mark was used. Five buckets were poured into the Wisconsin net for a total volume of 60 liters. After the water was passed through the net, the bucket was removed and the contents carefully rinsed into a glass jar. Except for the infrequent cases when formalin was added in the field, all plankton samples were returned to the lab alive. If the samples were not counted within the next day and a half, they were preserved in formalin. Final concentration for all preserved specimens was 5% formalin.

Various difficulties were encountered. During winter operations, freezing of the net produced obvious problems. At some Millers River stations

waters polluted with pulp and debris would clog the mesh of the plankton net bucket. Finally, because no meter device is used, the actual volume of water passing through the net during vertical hauls is unknown and probably less than the theoretical volume.

(5) Collection of Benthic Organisms

Whenever possible the Ekman Bottom Sampler or a Peterson Dredge was used to collect bottom samples. The heavy Peterson Dredge was usually operated from a boat crane, but the Ekman Sampler was operated either from shore or a boat, depending upon the station. Many of the locations, especially the riverine stations, had rocky bottoms so that the Ekman Sampler or Peterson Dredge could not be used. In those instances, a Surber Sampler, or most often, a shovel and D-net were used to collect benthics. Care was exercised to obtain quantitative and representative samples. Finally, when none of these measures was possible, large rocks were collected and placed in buckets of water, to be later scraped and analyzed for benthic organisms. Our experience agrees with Hynes (1971) who reviews the evidence and states that all methods of collecting stream benthics are biased in favor of some animals and less for others, and that there is no single satisfactory method.

(6) General Procedures

All water samples were usually placed in large, plastic, insulated containers with ice to keep them cool while in transit to the laboratory

for analysis. During the winter months the samples were packed in snow to prevent them from freezing.

In the winter, holes were cut through the ice surface with a combination of auger, saw, and chipper. The size of the hole depended upon what parameters the water was being sampled for, and which instruments had to be lowered through the hole in the ice.

Each container (plastic bottle, glass jar, bucket) had a number which was entered on an appropriate field control sheet. Field control sheets contained all pertinent information, including station codes, date and container numbers. Each analyst, whether in-house or at a subcontractor, received a receipt form with the sample code numbers and date only at the time of sample delivery.

B. Laboratory Methods

(1) Physical Chemical Tests of Water

After the water was delivered to the laboratory, the following parameters were measured, usually in the sequence listed:

Odor. No quantitative procedure was used. Freshly collected water was used. Freshly collected water was allowed to come to room temperature, and any odor present was judged qualitatively as suggested in Standard Methods (APHA, 1965).

Dissolved Oxygen. The standard Winkler method of titration was used. All reagents were checked at appropriate intervals, and when not in use were stored in a refrigerator.

pH. A Beckman pH meter previously standardized with a standard buffer solution was used for making pH measurements. Samples were placed in 100-ml beakers and allowed to stand at room temperature. A magnetic stirrer was used to stir the sample, and the pH was recorded after the reading had stabilized.

Turbidity. Originally a B & L Spectronic 20 spectrophotometer was used. A table based on a formazin standard was used to obtain the turbidity in Jackson Units (Hach Chemical Company, 1969). Later, a Hach Turbidimeter (Model 860A) which is a true nephelometer was used and the turbidity readings were generally lower. This instrument has its own calibrating rod using formazin as a turbidity standard, and it can be read directly in Jackson Units.

Specific Conductance. Specific conductance was obtained with a Conductivity Bridge Meter (RC-16B2). Unfiltered water was read directly for conductance and the temperature was recorded. Values were then converted and expressed in μmhos/cm @ 25°C.

Color. Unfiltered water was placed in Nessler tubes and compared with matched Nessler tubes filled with chloroplatinate color standards (Standard Methods, APHA, 1971). If the water was too turbid, the water sample was centrifuged before testing against the color standards.

(2) Other Chemical Tests for Water

The parameters described in this section were carried out by standard colorimetric methods or atomic absorption spectroscopy using a Perkin-

Elmer 403 atomic absorption spectrometer. All analyses involving titration were done in Class A burets. All water used in the analyses was purified by passing tapwater through an activated carbon filter, two mixed-bed deionizing columns in series and finally, a 0.22 μ particle filter. The water thus obtained consistently had a resistance of 10 megohms or more.

Alkalinity. A 100-ml sample was titrated with 0.0200 NH_2SO_4 using Brom Cresol Green - Methyl Red indicator; the endpoint was taken at the gray intermediate color of the indicator. Results were reported as μg $CaCO_3$/ml (ppm).

Carbon Chloroform Extract. The method used was a modification of that given in Standard Methods; the changes were in size of equipment and volume of sample tested. A sample (usually 4 liters) was passed through activated charcoal, washed, and the charcoal extracted with chloroform. The chloroform was evaporated in weighed dishes and the residue weighed to the nearest 0.1 mg. The results were reported in μg residue/ml (ppm).

Chemical Oxygen Demand. COD was determined using the method given in the FWPCA Methods (1969). Organic and oxidizable inorganic substances were oxidized by potassium dichromate in 50% H_2SO_4. The excess dichromate was titrated with standard ferrous sulfate using ferroin indicator. The results were reported as μg O/ml (ppm).

Hardness. Because of the inherent difficulties associated with the complexometric titrations of hardness, this parameter was obtained by combining the Ca and Mg levels determined by atomic absorption spectroscopy.

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The Ca and Mg were converted to $CaCO_3$ and reported as such, i.e., Hardness (µg $CaCO_3$/ml, ppm) = (ppm Ca x 2.5) + (ppm Mg x 4.1).

MBAS. Methylene Blue Active Substances, i.e., detergents, were determined by extraction of the anionic detergents into toluene with buffered methyl green (methyl green is more reliable than methylene blue). The intensity of the blue color developed in the presence of detergents was read spectrophotometrically. The results were reported as µg Alkyl Benzene Sulfonate/ml (ppm).

Metals and Other Elements. The metals listed below were all determined by atomic absorption spectroscopy using an automated Perkin-Elmer 403 spectrometer. The instrument settings and conditions used were those suggested by Perkin-Elmer in their instrument handbook; in some cases, minor modifications were used which increased the sensitivity and/or precision. All sample runs were preceded by standard samples which spanned the range of values found in the samples.

Aluminum	Lead
Arsenic	Manganese
Barium	Potassium
Boron	Selenium
Cadmium	Silicon
Cobalt	Silver
Copper	Sodium
Total Iron	Uranyl ion
	Zinc

Hexavalent Chromium. Hexavalent chromium, or chromate, was determined using the pink-colored dye formed when chromate reacts with 1,5-diphenylcarbohydrazide. The intensities were determined spectrophotomet-

rically. The results were reported as μg Cr(VI)/ml (ppm). Total Cr was also determined by atomic absorption.

Ferrous Iron. Iron (II) was determined as the o-phenanthroline complex colorimetrically. Reported as μg Fe/ml (ppm).

Ferric Iron. Obtained by subtracting ferrous iron from total iron.

Mercury. A 100-ml sample was treated with potassium permanganate to remove organic material, hydroxylamine to remove the excess potassium permanganate, and stannous chloride to reduce mercury to the element; mercury vapor was swept out of the solution with a stream of nitrogen and the mercury absorption measured using a Coleman mercury analyzer. The results were reported as μg Hg/ml (ppm).

Chloride. A 100-ml sample was titrated with 0.0141 N $Hg(NO_3)_2$ using diphenylcarbazone as the indicator. The endpoint was taken as the first permanent faint purple color. The results were reported as μg Cl/ml (ppm).

Cyanide. Cyanide (free) was determined colorimetrically using the pyridine-pyrazalone method given in Standard Methods. Results were reported as μg CN/ml (ppm).

Fluoride. Determined colorimetrically using the SPADNS method cited in Standard Methods. Initially the results were checked using a fluoride specific electrode. The results were reported as μg F/ml (ppm).

Sulfate. Sulfate sulfur was determined turbidimetrically as $BaSO_4$ upon the addition of barium chloride and a gelatin stabilizer. Turbid samples were filtered before analysis, and colored samples were measured against

pure water for correction. Results were reported as µg S/ml (ppm).

Ammonia Nitrogen. Ammonia was determined by direct Nesslerization; at first, tests were made to determine that the hardness levels encountered did not interfere with the direct analysis. Initially, samples were run on filtered and unfiltered water (0.45 µ filter). Since no difference was found between the two, it was assumed that all ammonia nitrogen was in solution and the filtration was discontinued. The results were reported as µg N/ml (ppm).

Nitrate Nitrogen. Nitrate was determined colorimetrically as the pink dye formed upon reduction of nitrate to nitrite which, in acid solution, couples via a diazotization process with 1-naphthylamine-sulfanilic acid. Both nitrate and nitrite in the sample are measured; nitrate is obtained by subtracting nitrite. The results were reported as µg N/ml (ppm). The filtered-unfiltered results were the same as those found for ammonia.

Nitrite Nitrogen. Performed as described for nitrate with the omission of the reduction step. Results were reported as µg N/ml (ppm).

Organic Nitrogen. Organic nitrogen was obtained by performing a total Kjeldahl nitrogen analysis; in this procedure, organic nitrogen is converted to ammonia, and determined as outlined above. The resulting value is the sum of ammonia due to free (dissolved) ammonia nitrogen and organic nitrogen. The values cited are those obtained by subtracting the value of ammonia nitrogen from the total. The method used was that given in the FWPCA methods (1969). Results were reported as µg N/ml

(ppm).

Total Phosphorus. The sample was digested (boiled) with H_2SO_4 and $HgSO_4$ to convert all phosphorus to orthophosphate. The orthophosphate thus formed was determined colorimetrically by the method given in the FWPCA manual (1969). The results were reported as µg P/ml (ppm).

Orthophosphate. Determined using the method cited above on an undigested sample. Results reported as µg P/ml (ppm).

Polyphosphate. Determined by digestion as described above with the omission of the $HgSO_4$. This converts all polyphosphates to orthophosphate; the polyphosphate level is obtained by subtracting the orthophosphate value from the value obtained here. Results were reported as µg P/ml (ppm).

Organic Phosphorus. Organic phosphorus was obtained by subtracting orthophosphate and polyphosphate from the total phosphorus. Results were reported as µg P/ml (ppm). Phosphorus analyses were performed on filtered and unfiltered samples to give a measure of the dissolved and particulate levels.

(3) Pesticide and Phenol Analyses

(a) Sample Handling

Coded samples were collected in one-gallon amber glass jugs with plastic screw caps. The sample bottles were thoroughly precleaned using the following sequence: detergent wash, rinse, chromic acid wash, rinse with tap water, distilled water, redistilled acetone

and pesticide quality hexane. The caps were lined with Saran or Teflon. Each sample consisted of 2 gallons. Upon receipt they were placed in a walk-in cold room at 4°C in the dark.

(b) Sample Analyses

In order to test for all the required parameters, each water sample was subjected to five different analytical procedures. The following classes of compounds were determined by these methods:

Total phenols
Chlorinated hydrocarbon insecticides
Organic phosphate insecticides
Carbamates (Carbaryl)
Herbicides

A one-liter portion was withdrawn from each water sample for determination of total phenols by the 4-aminoantipyrine colorimetric method as described in Standard Methods (APHA, 1965). One sample from each day's collection was steam distilled prior to analysis in order to achieve greater sensitivity. The others were extracted and analyzed directly by a simplified aminoantipyrine method. In this way all samples collected on a given day could be analyzed during the same day as specified for phenolic compounds in water.

Solvent extracts of the water samples were prepared for the analysis of pesticides. A 2-liter aliquot of sample water was extracted with two 60-ml portions of 15% ethyl ether in hexane followed by a third extraction with 60 ml of hexane alone after addition of 70 ml of sodium sulfate-saturated water to the sample. The combined

extracts were dried over anhydrous sodium sulfate and concentrated to a final volume of 1 to 2 ml. These procedures for sample preparation were similar to those found in the EPA Manual (1971). This concentrated extract was used for the determination of chlorinated hydrocarbons by gas liquid chromatography (GLC) with electron capture (EC) detection, soluble organic phosphates by GLC with alkali flame ionization detection (AFID), and carbaryl by photofluorometry. For the herbicidal acids (2,4-D, 2,4,5-T, and 2,4,5-TP) a fresh one-liter aliquot of water sample was extracted with ethyl ether.

The gas chromatographic parameters used were as follows:

Instrument - Varian Aerograph Model 1400, equipped with interchangeable tritium-source electron capture detector and alkali flame ionization detector.

Column - Coiled glass (6 ft. x 2 mm ID) packed with 1.5% OV-17/1. 95% QF-1 on Supelcoport 100/120 mesh.

Carrier gas- Prepurified N_2, 40 ml/min, 45 psi

Temperature- Inlet, 225°; column, 200°; detector, 220°

Although the standard references and many other references were consulted for guidelines in optimizing gas chromatographic conditions for the pesticides of interest in this study, the information reported by Thompson, et al. (1969) and Leoni and Puccetti (1969) were the most useful. Under these conditions, with the EC detector, it was possible to separate and detect all of the required organochlorine insecticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hepta-

chlorepoxide, lindane, methoxychlor, and toxaphene). Organophosphates would also be detected with the EC detector if they were present in the same sample concentrates but the specificity would be limited. To check for the presence of phosphorus-containing compounds each sample was rechromatographed after replacement of the EC detector with the AFID which is specifically sensitive to phosphorus. Appropriate standards were used as controls for the analytical procedures.

A procedure was not available for total pesticidal carbamates. The most widely used substance in this class is probably carbaryl (Sevin); thus a fluorimetric method that would measure carbaryl and its product of hydrolysis (1-naphthol) was used (Argauer et al., 1970). Appropriate aliquots from the same sample concentrates that were used for gas chromatography (above) were extracted with 0.25 N sodium hydroxide and the fluorescence compared with standards in an Aminco-Bowman Spectrophotofluorimeter set at excitation and emission wavelengths of 335 nm and 465 nm, respectively.

Finally, the herbicides were determined by EC-GLC after esterification with chloro-ethanol as described by Woodham et al. (1971). This involved extraction of an acidified water sample with diethyl ether, reextraction of the ether solution with 0.5 N sodium hydroxide, reextraction of the acidified aqueous phase again with ether, and finally reaction of the ether extract residue with borontrichloride-

chloro-ethanol reagent to form the chloroethyl ester derivatives of the phenoxy acids.

(4) Analyses of Algae (Phytoplankton)

All samples were usually processed within 12 hours after collection. Occasionally, samples were preserved by adding formalin (final conc. 5%). Samples were shaken to evenly distribute the phytoplankton, and subsequently each sample was processed by the continuous centrifuge technique (Standard Methods, APHA, 1965). Concentrated samples were examined in a Sedgwick-Rafter counting cell with the aid of a calibrated microscope. Both total and differential counts were done, and all values were converted to numbers of organisms contained in one liter of the original sample.

(5) Bacteriological Tests

All samples were processed within 12 hours after collection. Analyses were carried out by means of the membrane filter technique (Standard Methods, APHA, 1971) using Millipore filters with a pore size of 0.45 μ. Three aliquots of appropriate volumes from each water sample were processed in duplicate for each of the three media used. After filtration, filters were placed in petri dishes on sterile pads saturated with the appropriate medium. Standard media, incubation temperatures, and counting procedures were used for the analyses of fecal coliform and total coliform bacteria (Standard Methods, APHA, 1971). Total heterotrophic bacteria were incubated at 20°C on pads saturated with Difco m-Plate Count Broth. Daily

counts of heterotrophic bacteria were made for nine days. After 9 days plates were refrigerated at 8°C for one day, and a final count was made. In addition to total counts, differential counts of chromogenic and non-chromogenic heterotrophic bacteria were made for each of the 10 days. The highest total count in this 10-day period was used to calculate the number of heterotrophic bacteria in 100 ml of the original water sample. The highest chromogenic count in this period was used to calculate the percent of the total heterotrophic bacteria in the original sample that was pigmented.

(6) Analysis of Zooplankton

The jars containing zooplankton were turned upside down twice for mixing. A medicine dropper was used to remove a portion of sample to a Sedgwick-Rafter counting cell. The cell was placed on a piece of paper ruled into 10 sections, and it was viewed with an overhead light with 50x magnification under a stereoscope. Total and differential counts were made, and after appropriate calculations, values were eventually converted to number of organisms per liter of water. The keys in Ward and Whipple, Freshwater Biology 2nd edition (Edmondson, 1959) were used for identification.

(7) Analysis of Benthic Organisms

(a) Initial Sampling in the Field

When time and weather permitted, some benthic samples were

processed in the field. For stony and rocky samples, the organisms were scraped off and the stones were discarded. For gravel or sandy samples, the samples were rinsed with water, the sand stirred by hand and the supernatant poured through a U.S. Standard No. 30 copper sieve to concentrate the organisms. Usually the samples were split in half, each half being rinsed about 10 times. The organisms were washed off the sieve by backpouring into a plastic bucket.

(b) Processing in the Laboratory

Initial processing was carried out as described above if not already done in the field. Most of the mud collected by the Ekman Sampler could be washed through the No. 30 mesh by rocking and submerging in a pail of water. After sieving, the remainder was backwashed into white enamel or plastic pans in a shallow layer of water. Debris was sorted out and organisms were lifted out with tweezers and placed in small petri dishes. They were then identified into major groups and counted with the aid of a stereoscope. Where possible, the organisms were expressed in number per unit area of substrate. The keys in Edmondson (1959) were used for identification.

APPENDIX 2

SUMMARY OF PERTINENT HYDROLOGICAL DATA*

1. Quabbin Reservoir

Area, June 1971		19,200 acres
Volume, January 1971		226×10^9 gallons
June 1971		253×10^9 gallons
December 1971		212×10^9 gallons
Projected Annual Input, 1971		
a) Swift River, East Branch		15.7×10^9 gallons
Swift River, Middle Branch		3.9×10^9 gallons
Swift River, West Branch		8.15×10^9 gallons
b) Ware River Diversion		10.68×10^9 gallons
c) Other Inputs**		49.12×10^9 gallons
	TOTAL	87.55×10^9 gallons
Projected Annual Losses, 1971		
a) Diversion to Wachusett		$.76 \times 10^9$ gallons
b) Chicopee Outlet		5.14×10^9 gallons
c) Surface Losses		11.5×10^9 gallons
d) Other Losses***		10.95×10^9 gallons
	TOTAL	103.59×10^9 gallons

*These data were supplied by the Metropolitan District Commission and the U. S. Army Corps of Engineers and were verified by them to be adequate assumptions for this report.

**Direct precipitation on reservoir surface and inflow from watersheds other than the Three Swift River Branches.

***Includes deep seepage and loss to bank storage.

2. Wachusett Reservoir

Area, June 1971	3,570 acres
Volume, January 1971	52.6×10^9 gallons
June 1971	49.7×10^9 gallons
December 1971	46.3×10^9 gallons
Projected Annual Input, 1971	
a) Diversion from Quabbin	76.0×10^9 gallons
b) Other Inputs*	48.0×10^9 gallons
Specific dates of operation of diversion from Quabbin	Jan 1-5; Jan 11-Feb 5; Feb 10-17; Feb 22-27; June 22-30
Projected Annual Losses, 1971	
a) Water Supply to Boston	104.2×10^9 gallons
b) Other Losses**	5.41×10^9 gallons

3. Average Daily Flow Rates, Quabbin Inputs for Period Mar-June 1971

a) Ware River Diversion	118.91 MGD
b) Swift River, East Branch	91.70 MGD
Swift River, Middle Branch	22.74 MGD
Swift River, West Branch	48.69 MGD
c) Other Inputs*	164.63 MGD
TOTAL	446.67 MGD

*Direct precipitation and inflow from surrounding watershed lands.

**Evaporation and deep seepage.

4. Connecticut River (at Montague City)

Average Daily Flow Rates, 1971

January	4,975 MGD
February	5,802 MGD
March	7,782 MGD
April	25,242 MGD
May	24,253 MGD
June	4,057 MGD

Specific dates proposed diversion would have been possible during Jan - June 1971:

Theoretical (T): March 18, 20, 21; May 27, 28

Most Probable (MP): April 3 - May 25

Average daily flow rate during this period	T: 25,147 MGD MP: 26,408 MGD
Percentage of Connecticut River flow volume ending up in Quabbin during this period	T: 1.491 % MP: 1.420 %
Total Volume added to Quabbin during this period	T: 21.75×10^9 gallons MP: 19.88×10^9 gallons

5. Ware River

Average Daily Flow Rates, 1971

January	39.13 MGD
February	58.16 MGD
March	129.30 MGD
April	286.86 MGD

May 141.48 MGD

June 49.45 MGD

Specific dates of Ware River diversion during this period:

Feb 18; Feb 28 - Mar 10; Mar 16 - May 28

Average daily flow rates during this period 192.85 MGD

Percentage of Ware River volume ending up in Quabbin during this period 55.92%

Total Volume added to Quabbin during this period 9.447×10^9 gallons

6. Millers River System

Average Daily Flow Rates, 1971 in MGD

Station	January	February	March	April	May	June
2	13.15	17.01	28.75	96.60	43.38	7.12
3	8.98	12.56	25.75	77.64	33.47	5.53
4		242.47	240.61	640.61	339.21	92.16
5		259.20	257.21	684.81	362.62	98.52
6 & 7	22.09	29.71	64.75	145.48	75.83	13.77
8	8.84	11.88	25.90	58.19	30.33	5.47
9	267.45	415.46	474.89	994.07	500.84	134.15
10	323.79	502.98	574.93	1203.48	606.35	162.19

The following figures apply to the final proposed diversion aqueduct from the Tully System to Quabbin:

Specific dates proposed diversion would have been possible during Jan-June 1971:

March 18, 20, 21; April 3 - May 23
(Total 54 days)

Average daily flow rate during this period	**334 MGD**
Percentage of Tully System flow volume ending up in Quabbin during this period	**67.1 %**
Total volume added to Quabbin during this proposed diversion period	**12.097×10^9 gallons**

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APPENDIX 3

MINUTES OF MEETING OF SEPTEMBER 16, 1971

Background Information

Mr. Everett L. Maynard of the Division of Water Hygiene, Environmental Protection Agency (EPA), now on assignment to the Corps of Engineers, made a trip on May 19-21, 1971 to Cincinnati, Ohio to discuss the proposed diversion of the Connecticut River into Quabbin Reservoir with Dr. James Symons of the EPA. A Trip Report was received by NER on July 7, 1971. The implications of the report were considered important enough for a separate meeting. Therefore, NER drew up a series of questions and forwarded them to the MDC and the Corps of Engineers. Subsequently, a meeting was held on September 16, 1971 to discuss these questions.

Appendix 3 includes the agenda for that meeting, entitled "Suggested Sequence for Discussion", a copy of the minutes of the meeting, held on September 16, 1971, and finally a verbatim copy of the Trip Report of Dr. Symons.

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Suggested Sequence for Discussion

1. Point of discharge of Connecticut River water into Quabbin

2. Hazards of discharging Connecticut River water into western arm of Quabbin

3. Tully River complex and Millers River diversion into Quabbin

4. Problems associated with diversion of Connecticut River waters into Quabbin

5. Nitrate and phosphate

6. Significance of stratification in Quabbin

7. Treatment of Connecticut River water

8. Treatment of Connecticut River water and bypass of Quabbin to Wachusett

Minutes of Meeting
September 16, 1971

Place of Meeting: Army Corps of Engineers, New England Division
Waltham, Massachusetts

Purpose of Meeting: To discuss contents of the trip report of Everett Maynard's visit with Dr. James Symons to discuss the proposed diversion of a portion of the Connecticut River into Quabbin Reservoir.

Persons in Attendance:

James Symons	Environmental Protection Agency Division of Water Hygiene
Everett Maynard	Environmental Protection Agency Division of Water Hygiene
Floyd Taylor	Environmental Protection Agency Division of Water Hygiene
George Camougis	New England Research, Inc.
Paul Erickson	New England Research, Inc.
Warren Zepp	New England Research, Inc.
O. T. Zajicek	University of Massachusetts
Joseph Ignazio	Army Corps of Engineers New England Division
Lawrence Bergen	Army Corps of Engineers New England Division
Paul Pronovost	Army Corps of Engineers New England Division
Martin Cosgrove	Metropolitan District Commission Construction Division

Thomas Baron	Metropolitan District Commission Construction Division
Leonard Fenocketti	Metropolitan District Commission Construction Division
Harold Willey	Metropolitan District Commission Construction Division
John Copithorne	Metropolitan District Commission Water Division
William Tompson	Metropolitan District Commission Water Division
Edward Tyler	Metropolitan District Commission Water Division

In his introductory remarks, Dr. Camougis suggested an agenda for the meeting which was accepted by all present. The following items refer to the items of that agenda:

Item 1. Point of discharge of Connecticut River water into Quabbin

Dr. Symons felt that it was best to be conservative and to be prepared for the worst possible case with regard to the Connecticut River diversion. The "Y" proposal offers the most flexibility. He said that there was always reason, if only on the basis of experience with other systems, to be concerned about short-circuiting in water supplies. Dr. Symons felt that the model studies should therefore be continued with simulations of wind and thermal stratification.

The MDC stated that provisions would be made in the proposed aquaduct to allow for the future addition of a diversion into the western arm if needed. The MDC agreed that more model studies were desirable.

Present standards for turbidity and impending new standards were mentioned. Turbidity requirements will be raised from 5 J.T.U. to 1 J.T.U. for potable water. Since this requirement must be met at the tap, and since there may be deterioration of water quality during delivery, reservoirs must produce water that is better than 1 J.T.U. Shaft No. 12 produces about 0.5 J.T.U. at present, but there was some speculation that the diversion of Connecticut River water could raise the turbidity in Quabbin Reservoir beyond permissible limits. There was a further discussion and concern over turbidity measurements. It was agreed that apparent discrepancies in measurements of turbidity constitute a complex methodological problem and should be examined.

Item 2. Hazards of discharging Connecticut River water into western arm of Quabbin

If Connecticut River water were discharged only into the western arm of Quabbin Reservoir, Dr. Symons felt that there would be few problems since a large dilution factor was involved. If water quality deteriorated at the Chicopee outlet, Dr. Symons felt that the outlet could be moved up to Shaft No. 12, which would allow for greater dilution.

The MDC did not agree with Dr. Symons that the Chicopee outlet could be easily moved. There were questions about the cost, but the MDC felt that the most prohibitive factor would probably be head problems associated with a longer pipeline.

The MDC also pointed out that the Chicipee outlet would run continuously during the Connecticut River discharge and they were concerned that the Chicopee

outlet would get direct draw of Connecticut River water if the diversion were in the western arm. The MDC also explained that Shaft No. 12 physically could not operate while the Ware River was being diverted, and that the proposed diversion dates for the Connecticut River are almost identical to those for the Ware River. Therefore, Shaft No. 12 would not be operating during discharge, thus minimizing any possible direct draw of diverted waters into Wachusett Reservoir.

The dilution figures for Quabbin Reservoir were explained. The western arm diversion would give a large dilution factor with respect to Shaft No. 12 since about 2/3 of the water volume in the reservoir is below an east-west line drawn through Shaft No. 12. A diversion into the middle arm would be diluted by only 1/3 of the reservoir under ideal conditions. If the Chicopee outlet is considered, the western arm diversion gives poor dilution at the Chicopee outlet since only 1/4 of the reservoir is available for dilution.

Dr. Symons at this point indicated that he preferred a split diversion to utilize the maximum possible amount of the hypolimnion volume to minimize depletion of the dissolved oxygen due to increased organic loads.

Dr. Zajicek did not foresee a problem with organic loading and depletion of dissolved oxygen since COD values for Connecticut River water, during freshet flow and Quabbin Reservoir water were similar. Values cited were:

10-15 ppm in the Connecticut River during freshet flow
5-10 ppm in northern Quabbin
about 5 ppm at Shaft No. 12

At this point, Mr. Maynard pointed out that Connecticut River COD values can be much higher than those given by Dr. Zajicek, and that those higher numbers posed

a real problem from diversion. It was recognized that the Connecticut River is extremely variable and the present data may not reflect the potential problem of diversion.

Dr. Symons asked for clarification of the degree of pollution in the Connecticut River. He had formed the impression that it was much worse than Quabbin Reservoir, but if data indicated that the Connecticut River was not that bad, Dr. Symons said that he was perhaps being an alarmist when he answered the various questions reported in the original trip report.

Item 3. Tully River complex and Millers River diversion into Quabbin

Dr. Symons felt that he was probably not accurate when he answered the question about the Tully and Millers systems. There were some communication problems and confusion about the relative descriptions of the Tully River complex and the Millers River. It was agreed that the Millers River was of poor quality. There was little further discussion on the Millers and Tully River systems.

Item 4. Problems associated with diversion of Connecticut River waters into Quabbin

All groups involved expressed concern over the possibility of short-circuiting, and although the diversion schedule and hydrodynamic studies may attenuate this concern, they cannot eliminate it.

Dr. Symons felt that the model studies did not eliminate the possiblity of short-circuiting if only because stratified waters were not considered, and stratified waters can have strange flow patterns. If short-circuiting were put in perspective, Dr. Symons felt that one or two unacceptable values during a year

would not bring legal action, so a diversion system would not have to be designed to accommodate the worst storm in a 100-year period. Furthermore, if a water treatment plant were placed below the Wachusett Reservoir, standards now applied to Quabbin waters could probably be relaxed. The people who spend the money would have to decide the size risk the consumers would take.

The MDC felt that short-circuiting of wind-driven water is minimized at all but the highest reservoir levels by glacial deposits in the northwestern area of the middle branch. A permanent baffle dam system was suggested as a possibility by Dr. Symons to maintain this pattern of flow at high reservoir levels.

Mr. Maynard expressed a concern over keeping diverted waters in the eastern reservoir where potential eutrophication problems could cause this area to become a "creeping cancer". Maynard preferred to dilute and mix the diverted waters within the entire reservoir.

Should diverted waters require treatment, Dr. Symons would prefer to treat them within an artificial area rather than in the reservoir itself, since more control is possible in an artificial area.

The MDC discussed a proposal for a prereservoir to monitor water quality. Poor quality water could be dumped into a tributary of the Millers River and be returned to the Connecticut River. Dr. Symons would prefer the prereservoir to damming the upper Quabbin Reservoir to form a separate basin.

Item 5. Nitrate and phosphate

The potential nutrient problem worried Dr. Symons and he recommended mixing

and algal growth potential studies in the laboratory to determine limiting nutrients and growth potentials.

Item 6. Significance of stratification in Quabbin

Stratification was considered reasonably covered during previous discussion.

Item 7. Treatment of Connecticut River water

Dr. Symons clarified the term "complete treatment" by explaining that it would be the treatment necessary to upgrade Connecticut River water to meet Public Health standards for potable water. If properly mixed with Quabbin Reservoir water, Connecticut River water may be acceptable with no treatment.

If Connecticut River water were treated before entrance into Quabbin Reservoir, possibly only coagulation and settling to remove turbidity would be necessary. Turbidity removal must be done prior to disinfection with chlorine. Nutrient removal, if necessary, could be performed at this stage. Dr. Symons did not think disinfection of Connecticut River waters before entry into Quabbin Reservoir was worthwhile unless the reservoir were to be used for bathing purposes. Disinfection could be done elsewhere. However, the introduction of undesirable biological species (e.g. fish) raises another issue.

Dr. Symons felt that viruses would be no problem if the water were disinfected after turbidity was removed. If the water is clear (<1 J.T.U.) after leaving Wachusett Reservoir, all viruses will be destroyed by a contact time of 30 minutes with a free chlorine residual of 0.3 to 0.5 ppm. A well-operated filter plant at Wachusett Reservoir should deliver water at about 0.5 J.T.U.

Item 8. Treatment of Connecticut River water and bypass of Quabbin to Wachusett

A bypass to Wachusett Reservoir was considered impractical due to the large capital investment for a system that would be idle most of the time.

At this point the MDC asked for an estimate of the time that untreated Connecticut River water could be diverted into Quabbin Reservoir with little or no damage. All parties agreed that a diversion of 3-5 years could probably be realized before serious damage to Quabbin might be expected to occur, but that additional monitoring of the reservoir must be done during diversion. With 3-5 years flexibility the MDC felt it would be better to treat any water quality problems after some actual experience with diversion than try to design treatment plants in the dark. The MDC also felt that an actual diversion would put pressure on the groups that were polluting the Connecticut River to stop, and that the quality of Connecticut River water entering Quabbin Reservoir could therefore probably be raised.

5555 Ridge Avenue, Cincinnati, Ohio 45268

October 8, 1971

Trip Report - Boston, Massachusetts

Dr. Pringle
Through: Mr. Robeck

Travel Order #	Dates of Trip
T2789481	Sept. 15-16, 1971

Purpose of Trip: To discuss the proposal to divert Connecticut River water into Quabbin Reservoir.

Persons Contacted: The meeting consisted of 7 persons from the Metropolitan District Commission of Boston, Massachusetts, 3 persons from the U. S. Army Corps of Engineers, 3 persons from New England Research, Inc., 1 person from the University of Massachusetts, Mr. Floyd Taylor of Region I, EPA, and the writer.

Observations, Evaluation and Conclusions: The meeting revolved mainly about a discussion of a trip report prepared by Mr. Everett Maynard, of the U. S. Army Corps of Engineers, a copy of which is attached. The personnel from New England Research, Inc. had reviewed Mr. Maynard's trip report and prepared a formal list of questions and comments, a copy is attached. A copy of the agenda is also attached.

Most of the discussion revolved around essential points: 1) would diversion of the Connecticut River water into Quabbin Reservoir influence the ecology of the reservoir itself, and 2) would the above mentioned diversion influence the quality of Boston's drinking water. The Metropolitan District Commission (MDC) reported that no diversion would take place for at least four years because of legislative delays, and time for construction of the diversion pipe line. During this time, additional hydraulic model studies are proposed by New England Research, Inc. to determine more completely the flow patterns to be expected in Quabbin Reservoir during the time of diversion. The MDC also stated that in their design of the diversion pipe line, they would build in the capability of a tee to permit diversion of some of the water into the west arm of Quabbin Reservoir, if this should ever be needed in the future. We all agreed that any ecological damage to the reservoir would develop slowly, and that if the water quality in the reservoir were closely monitored after diversion began, changes could be made in the diversion scheme if any deteriorating quality were detected. I continued to insist that maximum dilution was essential to maintaining water quality, and I found the MDC's suggestion of building a low dam between two islands in the central arm of the reservoir to further

prevent short-circuiting at higher water levels encouraging.

I also continued to press for some sort of filtration for Boston's water supply. Mr. Taylor and I discussed the proposed new turbidity standard of 1 T.U., and the Division's general policy that all surface waters should receive some turbidity control. I said that although the present water quality of Boston met the Drinking Water Standards, that a relatively small, high-rate, direct filtration plant would serve as a vital additional protection for the consumers in the MDC service area. While the MDC seemed inclined to link any deterioration of the water quality in Quabbin Reservoir, because of diversion, to the necessity for filtration of their water, I ask that the question of filtration be considered independently of any change in water quality in Quabbin Reservoir.

Recommendations and Conclusions: The meeting was a very useful exchange of ideas for all the parties involved with the project. I think that the course of action selected by the MDC is wise, but I do hope that they will continue to investigate the actual cost involved of filtration of their water supply.

James M. Symons
Chief, Control Technology
Water Hygiene Division

JMSymons:ml

cc: Floyd Taylor

APPENDIX 4

OUTSIDE CONTACTS AND INFORMATION SOURCES

Considerable information and technical data were supplied to us by the MDC and the Corps of Engineers as this project progressed through the various stages. In addition, we have made contacts with several organizations, from which we have received both verbal and written information. We are grateful for their assistance and cooperation. The list of contacts appears below.

Central Massachusetts Regional Planning Commission
Worcester, Massachusetts 01609

Division of Fisheries and Game
Commonwealth of Massachusetts
Westboro, Massachusetts 01581

Division of Water Pollution Control
Water Resources Commission
Commonwealth of Massachusetts
Boston, Massachusetts 02202

Franklin County Department of Planning
Greenfield, Massachusetts 01301

Lawrence Experiment Station
Massachusetts Department of Public Health
Lawrence, Massachusetts

National Technical Information Service
U. S. Department of Commerce
Springfield, Virginia 22151

Northeast Utilities Service Company
Hartford, Connecticut 06101

U. S. Geological Survey
Department of the Interior
J.F.K. Federal Building
Boston, Massachusetts 02203

Vermont Yankee Nuclear Power Corporation
Rutland, Vermont 05701

Water Resources Research Center
University of Massachusetts
Amherst, Massachusetts 01002

Webster-Martin, Inc.
South Burlington, Vermont

APPENDIX 5

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APPENDIX 6

FOURTH QUARTER RESULTS

A. Preface

The data from October and November, 1971 were examined in the light of the discussion of data for the period from December 1970 through September 1971. Data were studied to determine if they contradicted or otherwise altered the conclusions that were drawn from the earlier data.

B. Biological Data

(1) Bacteria

Bacterial data collected during the fourth quarter were consistent with the data collected during the first three quarters. In general, numbers of heterotrophic bacteria in the reservoir systems increased from the first quarter to a peak in the second or third quarter, and decreased during the fourth quarter. This trend was observed at most reservoir stations; and is commonly observed in lacustrine environments. Numbers of heterotrophic bacteria at individual riverine stations usually remained the same or slightly increased from third to fourth quarters.

No general trends were noted in riverine, or lacustrine systems with respect to total coliform or fecal coliform bacteria. Riverine stations and Quabbin "inside"stations usually showed no change or slight increases in total coliform bacteria from third to fourth quarters. Other reservoir stations showed small changes in populations and followed no discernable pattern.

No pattern of changes in fecal coliform numbers was detected at any stations except those from the Quabbin "outside" system where stations showed fecal coliform numbers decreasing from the third to the fourth quarters.

(2) Phytoplankton

The frequency of occurrence of most algal types dropped from the third quarter to the fourth quarter for all systems studied. Pennate diatoms, however, did not change from the third quarter. This group occurred frequently during each quarter and was usually found in high concentrations (about 10^3 cells/liter) in all systems. Golden-brown flagellates occurred more frequently and usually in higher concentrations (about 10^3 cells/liter) during the fourth quarter in all systems except the Millers and Connecticut River systems.

(3) Zooplankton

During the fourth quarter, the numbers of crustaceans and rotifers remained at low values or decreased from summer or fall peaks at most stations. However, Quabbin Reservoir stations and the Millers and Connecticut River systems showed small peaks in numbers of rotifers during October with a decline in numbers during November. The average, relative composition of zooplankton populations in the reservoir systems varied little from third to fourth quarter, although the absolute numbers of each type did change in the manner noted above.

(4) Benthic Organisms

Fourth quarter benthic samples were collected in the reservoirs during late September and were discussed fully in Section 5. Riverine benthic samples were collected later and were not discussed. Fourth quarter riverine benthic data, however, followed the same general patterns presented in Section 5 and the discussion can be considered complete.

C. Chemical Data

In general the results shown in the fourth quarter data for chemical parameters support the discussions in Section 5 based upon the data for the first three quarters.

All parameters that were not discussed in Section 5 because they were rarely or never detected, were not detected during the fourth quarter. Sulfate sulfur was detected, but little significant variation in values in time and at various sampling stations was seen. All parameters that were discussed in Section 5 showed fourth quarter values that supported the conclusions already presented in the report.

D. Physical Data

(1) Color

If systems are arranged in order from highest to lowest average color based on fourth quarter data alone, the resulting pattern is the same as

that given in Section 5.

The group of river stations, R2, R3 and R6 showed a slight downward trend in color values during the fourth quarter, while other river stations showed an upward trend. The Quabbin "outside" and Wachusett systems and station Q9 from Quabbin "inside" showed little change in color in the fourth quarter, while all other Quabbin "inside" stations showed a slight increase in color.

(2) Specific Conductance

The pattern obtained by arranging systems in order of decreasing specific conductance is the same for the fourth quarter as that reported in Section 5 for earlier quarters.

There was a slight increase in specific conductance in the Connecticut River, a slight drop in the Tully and Ware system and a larger drop in specific conductance values for the Millers River for the fourth quarter.

(3) Dissolved Oxygen

All systems showed an increase in dissolved oxygen (from about 8 mg/l to 10 mg/l) during the fourth quarter, but these increases were small except in the Millers River where there was a ten-fold increase in dissolved oxygen values at South Royalston (R9), from low summer values of 1 mg/l up to 10 mg/l. The Millers River system as a whole went from a third quarter average of 5.5 mg/l to a fourth quarter average of 8.7 mg/l.

(4) pH

The Millers River and Ware River stations decreased slightly in pH during the fourth quarter while the Connecticut River increased slightly. The tributaries to the Millers River (R2, R3, R6, R7) increased in pH early in the fourth quarter then dropped back to levels that were observed late in the third quarter. The pH of the reservoirs decreased slightly.

(5) Turbidity

The fourth quarter pattern obtained by arranging systems in order of decreasing turbidity is identical to that in Section 5.

There was a large fourth quarter increase in turbidity at the Millers River stations (from 16 units to 32 units), while the Connecticut River increased slightly (from 3 to 4 units). Other systems showed only small fourth quarter changes in turbidity.

(6) Temperature

The temperature at all stations dropped in the fourth quarter. The reservoirs and the Connecticut River cooled slowly, dropping from 17-19°C in October to 9-11°C in November. The smaller rivers however, declined more rapidly, dropping from 12-18°C in October to 2-6°C in November. Some shallow reservoir stations (Q4, Q5) cooled almost as rapidly as the rivers.

E. Pesticide Data

All samples except two had no detectable pesticides or phenolic compounds during the fourth quarter. In November a presumptive value of 0.0002 ppm O, P -DDD was detected at Q3 and less than 0.01 ppm phenolic compounds was detected at Q2 at a depth of ten meters.

F. Radioactivity

There was no detectable gross alpha activity in any sample during the fourth quarter. All samples had gross beta activities below 10 μμC per liter during the fourth quarter except for a sample from Q8 at a depth of 10 meters. This particular sample had a gross beta activity of 18 μμC per liter. Since this was the only sample throughout the year which had high beta activity, it is difficult to draw any conclusions about the significance of this value.

G. Summary

The data collected during the fourth quarter are consistent with the conclusions drawn in the main report. The data follow trends that might be expected from seasonal variations in lacustrine and riverine environments. Variations that might be expected between relatively clean and relatively polluted riverine environments were noted when systems such as the Tully System and the Millers River were compared.

Fourth quarter data constitute a continuation of the patterns discussed in Section 5 of this report. No trends were noted during the fourth quarter

that contradicted the conclusions drawn from the patterns observed in data from the first three quarters. The additional data did not contain new patterns that would add to the conclusions already drawn.

96th Congress, 2d Session - - - - - - - - - - - - - - - - House Document No. 96-285

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT SURVEY REPORT

LETTER

FROM

THE SECRETARY OF THE ARMY

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY, DATED SEPTEMBER 10, 1976, SUBMITTING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, ON NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT. THE REPORT HAS BEEN PREPARED IN PARTIAL RESPONSE TO THE NORTHEASTERN UNITED STATES WATER SUPPLY STUDY LEGISLATION ENACTED OCTOBER 27, 1965, UNDER TITLE I OF PUBLIC LAW 89-298

IN TWO VOLUMES
VOLUME II

MARCH 19, 1980.—Referred to the Committee on Public Works and ordered to be printed with illustrations

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U.S. GOVERNMENT PRINTING OFFICE

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NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

Volume	Contents
I	Main Report
	Appendix A - Economic Development
	Appendix B - Future Population and Water Demand Studies
	Appendix C - Tunnel Geology and Cost Estimates
	Appendix D - Water Quality Studies of Connecticut and Millers Rivers and Quabbin and Washusett Reservoirs
II	Appendix E - Possible Effects of Various Diversions from the Connecticut River (or its estuary)
	Appendix F - Identification and Assessment of Social and Economic Impacts - Connecticut and Millers River Basin Diversions
	Appendix G - Environmental Protection Agency Report on Water Quality Studies
	Appendix H - Open Planning Program
	Appendix I - Effect of Diversion Control Flow on Project Yields and Cost of Water Delivered
	Appendix J - Letters of Comment
	Statement of Findings
	Final Environmental Impact Statement

APPENDIX E

POSSIBLE EFFECTS OF VARIOUS DIVERSIONS FROM THE CONNECTICUT RIVER (ON ITS ESTUARY)

This appendix contains a report by Essex Marine Laboratory for the New England Division, U. S. Army Corps of Engineers, on the probable impacts of upstream fresh-water diversion on the Connecticut River Estuary. Specifically, seven different diversion rates were tested for each of two cases. The first case involved diversions only when the flow at the U. S. G. S. gaging station at Montague City, Massachusetts was above 17,000 cfs; the second involved diversion when the flow at the gaging station was above 12,000 cfs. Investigations of the possible effects of diversions were divided into five areas of concern: 1) the hydrological regimen; 2) the benthic community; 3) the microbiological community; 4) the resident and anadromous fish other than adult American Shad; and 5) the adult American Shad, striped bass and the Atlantic Salmon. Results of these investigations for the various diversion rates were analyzed to determine the effects of the specific alternative projects on the estuary. The Environmental Objective section of the Project Impact Analysis and the Environmental Impact Statement utilized this background data to develop possible impacts of the projects.

POSSIBLE EFFECTS OF VARIOUS DIVERSIONS FROM THE CONNECTICUT RIVER

A report to the U. S. Army Corps of Engineers
under Contract No. DACW 33-71-C-0066

Essex Marine Laboratory
Essex, Connecticut
May, 1972

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INTRODUCTION

This report is submitted in satisfaction of the conditions of Contract No. DACW 33-71-C-0066 awarded by the New England Division of the U. S. Army Corps of Engineers to Essex Marine Laboratory, Inc., Essex, Connecticut. The scope of the study is defined in the contract in the following language: "to predict the probable impact of upstream freshwater diversion, during spring freshet periods, on the salinity-temperature regimen of the Connecticut River Estuary and to further correlate these changes with possible effects on the biotic community of the estuary." The contract requires that the effects of diversions at Northfield Massachusetts of 600, 800, 1000, 1600, 2000, 3000, and 4000 cubic feet per second be tested in each of two cases: first, when the average daily discharge at the United States Geological Survey's gauging station at Montague City, Massachusetts is 12,000 cubic feet per second or above, and second, at an average daily discharge at Montague City of 17,000 cubic feet per second or above. These discharges (i.e. 12,000 and 17,000 cfs) are being considered as alternative rates below which no diversion will take place, and are referred to as control flows. For the purposes of this study the Connecticut River Estuary is defined as that part of the Connecticut River lying below the Enfield Dam. Spring freshet is defined as that period in the spring of the year during which no upstream flow is recorded at the United States Geological Survey's gauging station at Bodkin Rock, near Middletown, Connecticut.

Figures 1-6 are intended to give a general view of the maximum diversions under consideration, and of the effects of the postulated control flows. The solid line represents daily flows at Thompsonville in thousands of cubic feet per second and the broken line represents flows at Thompsonville after the diversion of 4,000 cubic feet per second limited by a 12,000 cubic foot per second control flow at Montague City. Reference axes are provided at 13,870 cfs and 19,619 cfs, which are the flows at Thompsonville which are equivalent to flows of 12,000 cfs and 17,000 cfs respectively at Montague City. Obviously, if the control flow is set at 17,000 cfs at Montague City, diversions shown on these charts below this rate would not occur.

The report is divided into five sections dealing with the possible effects of diversions on: 1) the hydrological regimen, 2) the benthic community, 3) the microbiological community, 4) the resident and anadromous fish other than adult American shad (Alosa sapidissima), and 5) the adult American shad, striped bass (Morone saxatilis), and Atlantic salmon (Salmo salar). Primary responsibility for each section, with the exception of the section on bacteria, was assumed by individual members of the staff of Essex

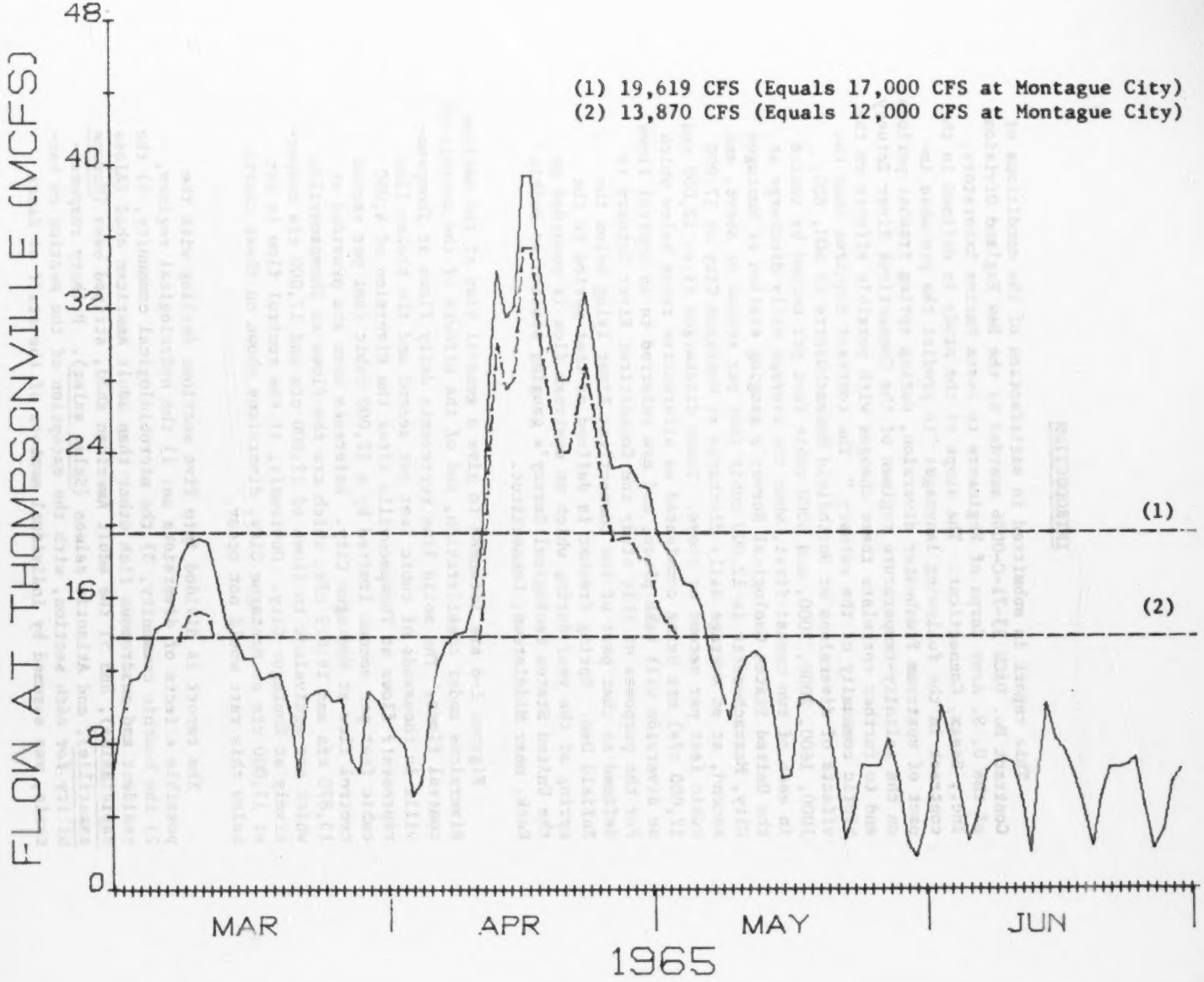
(1) 19,619 CFS (Equals 17,000 CFS at Montague City)
(2) 13,870 CFS (Equals 12,000 CFS at Montague City)
FLOW AT THOMPSONVILLE (MCFS)
48
40
32
24
16
8
0
(1)
(2)
MAR
APR
MAY
JUN
1965

Figure 1

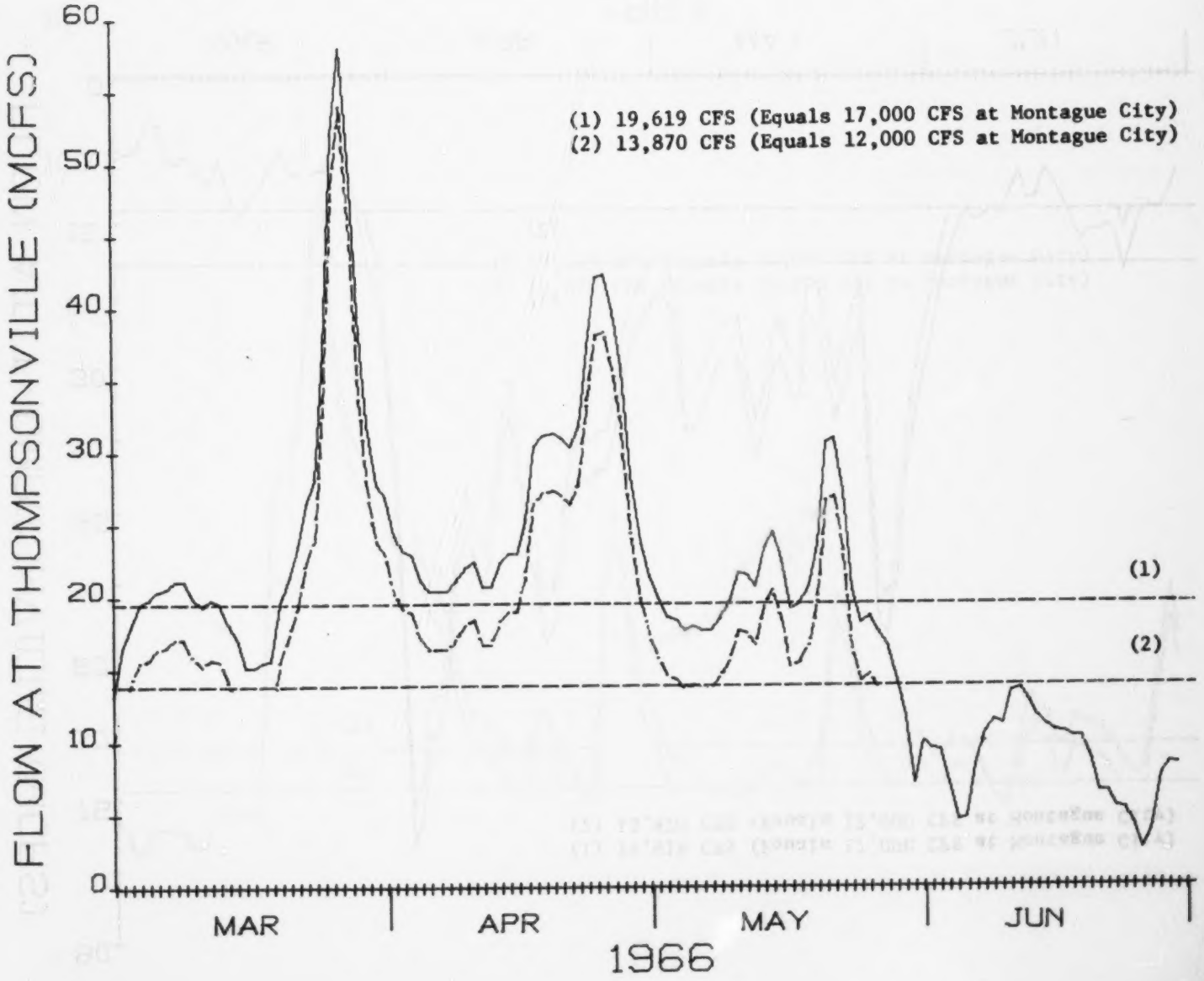
FLOW AT THOMPSONVILLE (MCFS)
60
50
40
30
20
10
0
(1) 19,619 CFS (Equals 17,000 CFS at Montague City)
(2) 13,870 CFS (Equals 12,000 CFS at Montague City)
(1)
(2)
MAR
APR
MAY
JUN
1966

Figure 2

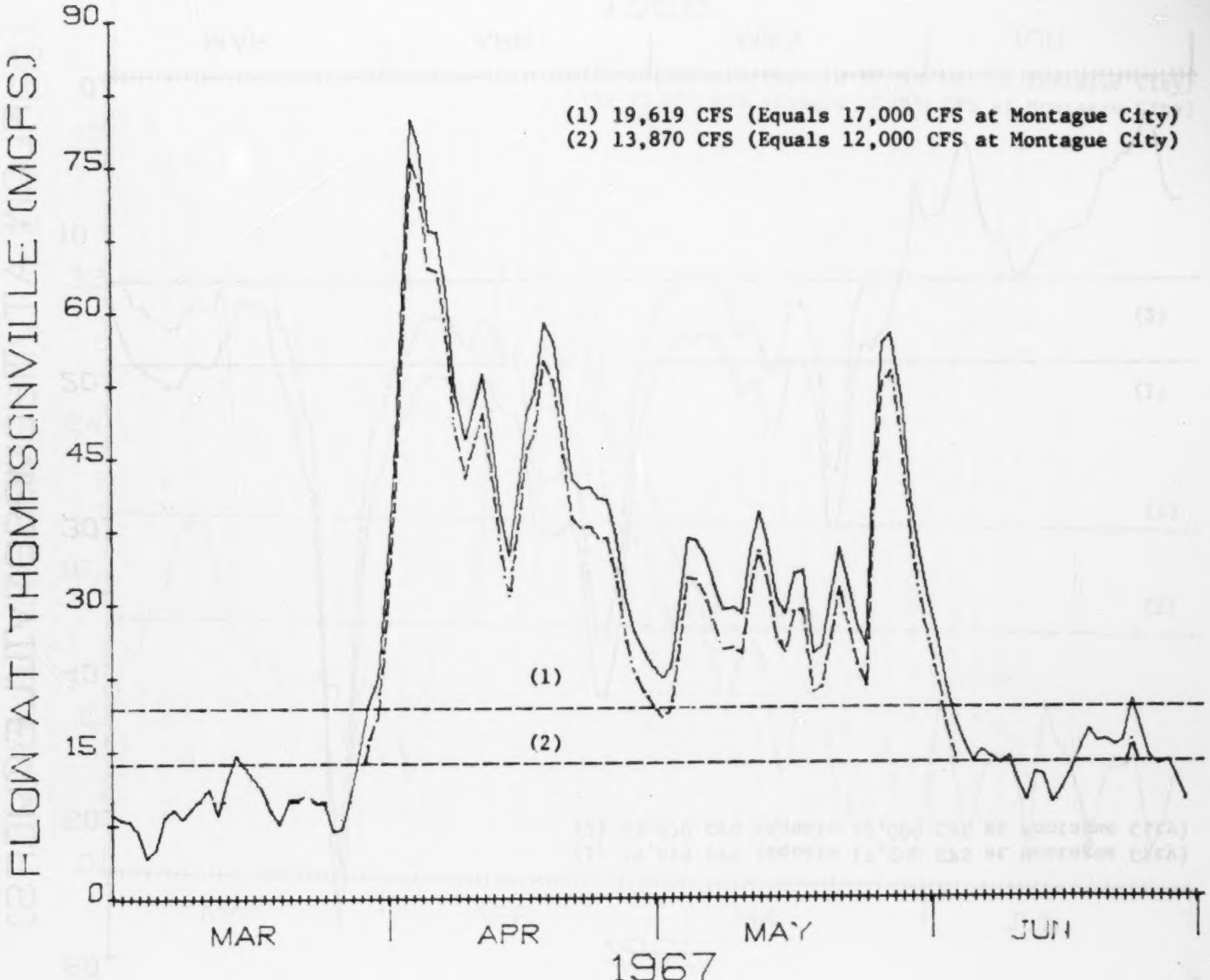
FLOW AT THOMPSONVILLE (MCFS)
90
75
60
45
30
15
0
(1) 19,619 CFS (Equals 17,000 CFS at Montague City)
(2) 13,870 CFS (Equals 12,000 CFS at Montague City)
(1)
(2)
MAR
APR
MAY
JUN
1967

Figure 3

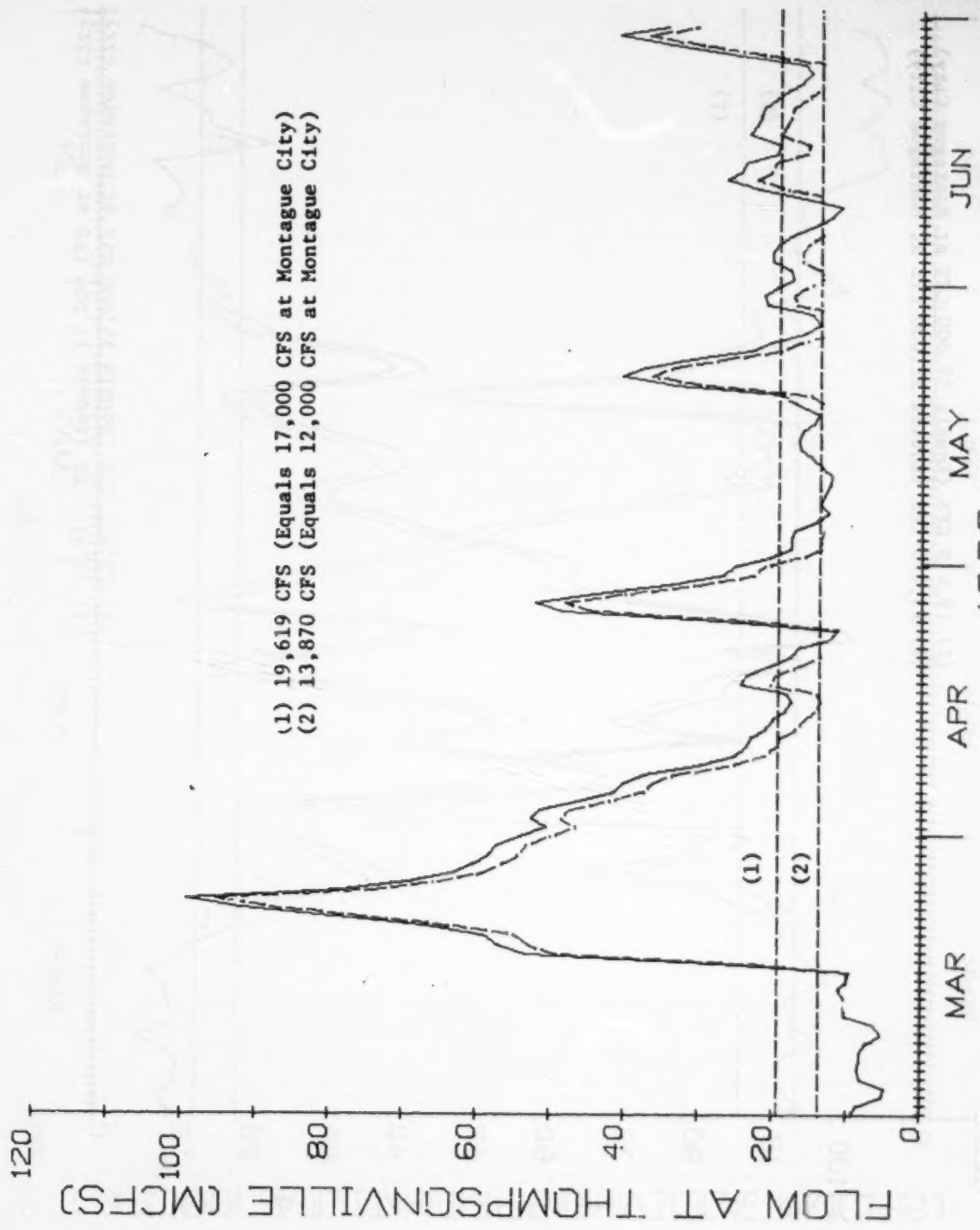

Figure 4

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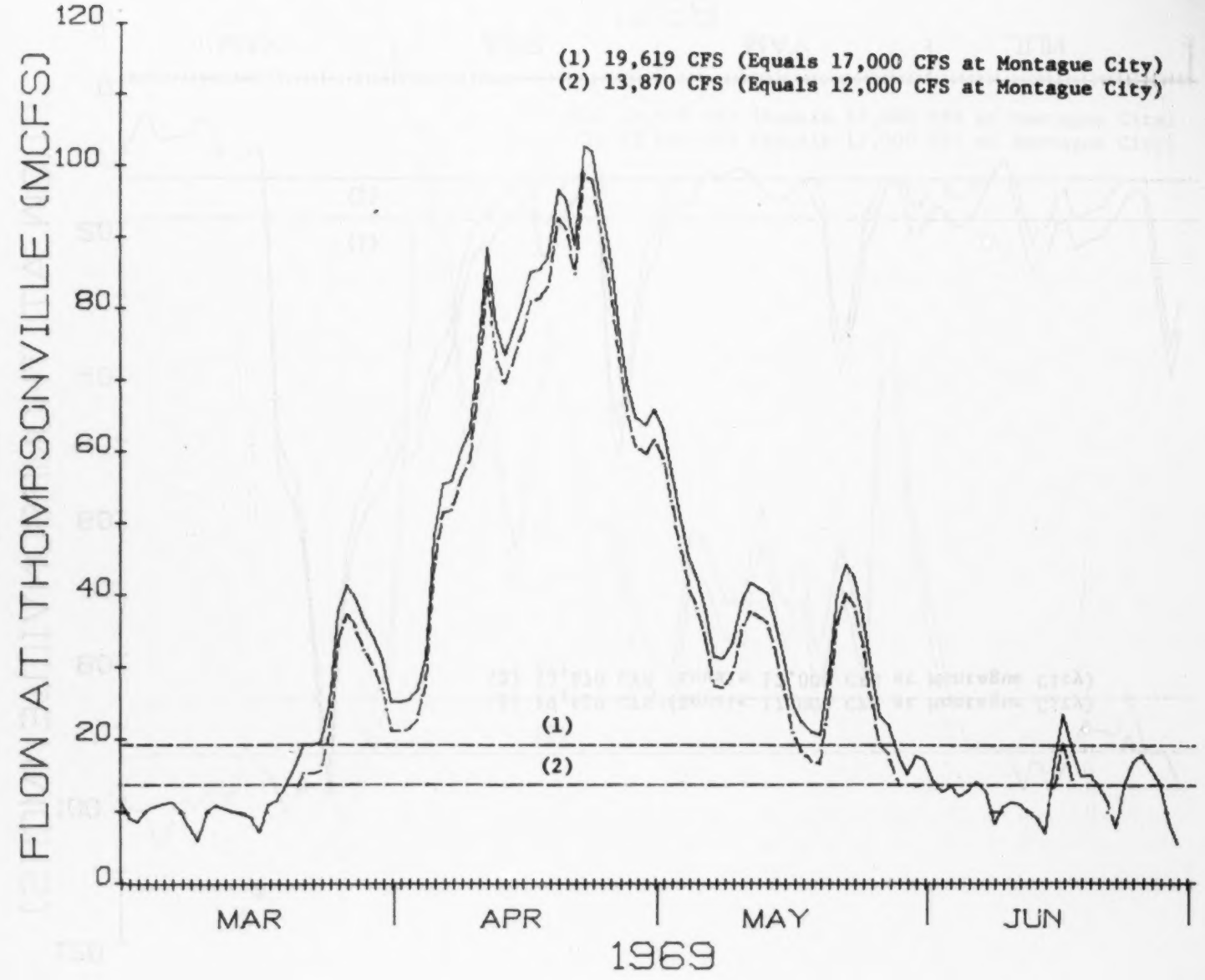
(1) 19,619 CFS (Equals 17,000 CFS at Montague City)
(2) 13,870 CFS (Equals 12,000 CFS at Montague City)
FLOW AT THOMPSONVILLE (MCFS)
120
100
80
60
40
20
0
(1)
(2)
MAR
APR
MAY
JUN
1969

Figure 5

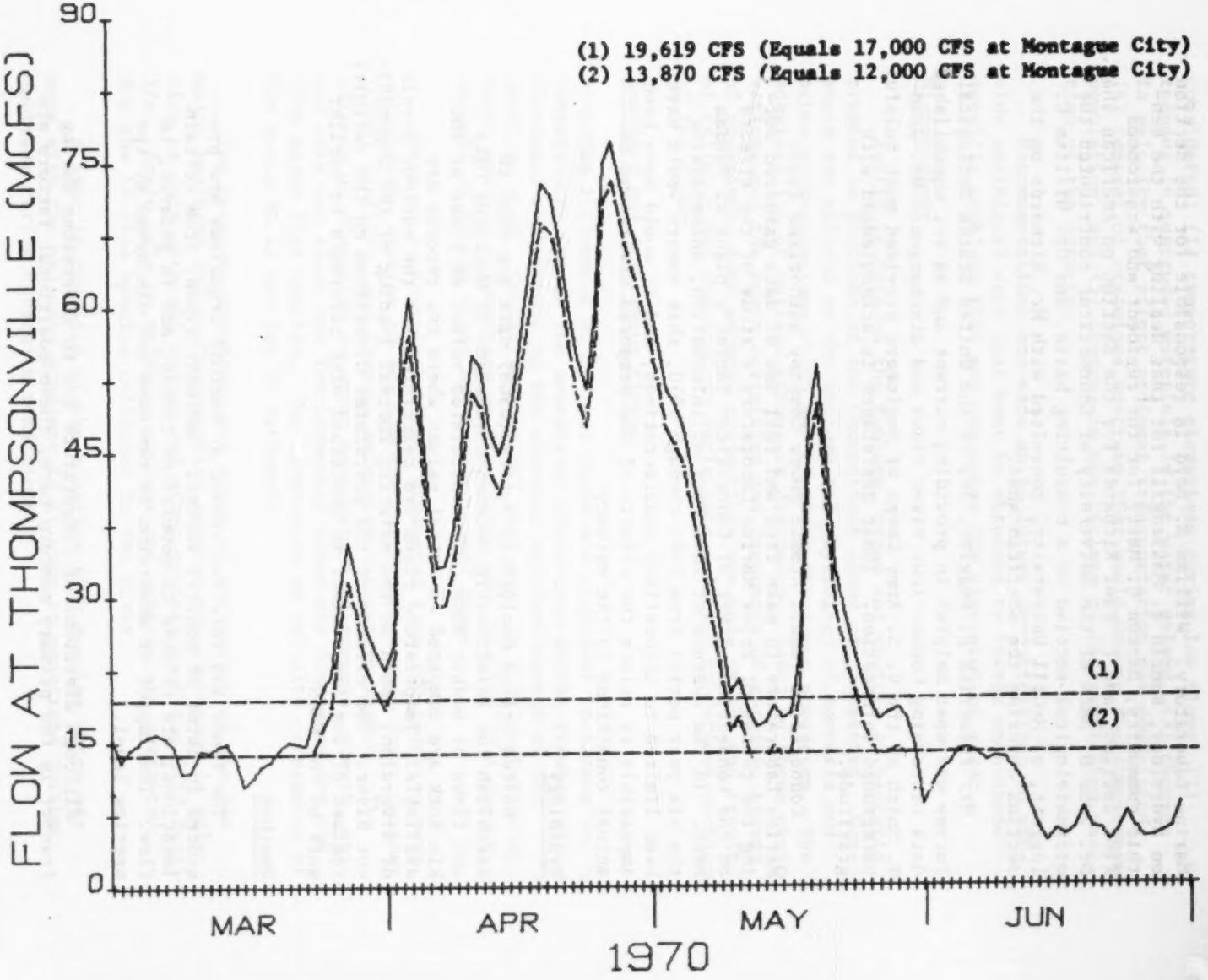
(1) 19,619 CFS (Equals 17,000 CFS at Montague City)
(2) 13,870 CFS (Equals 12,000 CFS at Montague City)
FLOW AT THOMPSONVILLE (MCFS)
90
75
60
45
30
15
0
(1)
(2)
MAR
APR
MAY
JUN
1970

Figure 6

Marine Laboratory. William A. Boyd is responsible for the section on hydrology, Ronald R. Massengill for that dealing with the benthic community, Barton C. Marcy for the resident and anadromous fish section, and F. Paul Richards for the section on American shad. Dr. John D. Buck of the University of Connecticut contributed the microbiological section on a consulting basis, and Dr. William C. Leggett, of McGill University, consulted with Mr. Richards on the section covering the American shad.

Mr. Frederick H. Ruggles, Jr. of the United States Geological Survey was most helpful in providing current and as yet unpublished data concerning Connecticut River flows and discharges. Mr. John T. Smith of the U. S. Army Corps of Engineers provided much helpful background information. Their assistance is acknowledged with gratitude.

Connecticut Yankee Atomic Power Company authorized Essex Marine Laboratory to make free and full use of data gathered during the course of Essex Marine Laboratory's study of the effects on the Connecticut River of Connecticut Yankee's plant at Haddam Neck. In the absence of this body of information, encompassing the six year period from 1965 through 1970, this report would have been limited to theoretical considerations, and it would have been impossible to relate the effects of the proposed diversions to actual conditions in the estuary.

Hydrology

United States Geological Survey (USGS) data are used to establish the relationship between discharges at Montague City and flows at Bodkin Rock. The calculated values of flows at Bodkin Rock are compared to actual values where the records are available. Temperature rises are calculated for the various levels of diversion, based on the existing thermal loading of the Connecticut River. The effects of the postulated diversions on the salinity regimen of the lower river is described with reference to earlier work by the USGS.

Benthos

The kinds and relative number of benthic organisms are presented in terms of monthly values. Sediment types, from certain locations, are related to population trends, and in general, to flow. The impact of diversion is reviewed and discussed at the species level.

Although elevation of temperature due to diversions during freshet is the primary concern here, these additional factors are

considered: (1) temperature elevations during low flows, (2) changes in suspended materials in the water column, (3) changes in velocity that affect sediment transportation and deposition, (4) removal of organisms upstream that would become the downstream population, and (5) changes in the biology of the euryhaline portion of the estuary.

Recommendations are made as to future investigations to provide additional data that must be obtained to better understand specific problems that may accompany the diversion of water.

Microbiology

Available data on the numbers, types and sources of bacteria present in portions of the Connecticut River are presented. Comments are offered on the ecology and physiology of bacteria and other microorganisms which may approach the river ecosystem. The adaptability of various groups is discussed. Based on these observations and the known activities and responses of specific groups of organisms, some general projections are made on the end results of salinity and temperature variations relative to various portions of the river.

Resident and Anadromous Fishes

The influences of reduced flows and resultant increases in temperatures due to the postulated diversions during freshet are discussed with regard to the spawning and development of the American shad. Collections of 869 shad eggs in 4,341 net-fishing hours provide information on the timing and location of spawning, as well as on egg sizes and developmental times.

Data on ichthyoplankton are presented from 700 plankton tows, entrainment studies at the Connecticut Yankee Atomic Power Company (CYAP) facility, and from an extensive literature search. The effects of diversion on upper temperature tolerances, growth, egg and yolk sac sizes and developmental times are discussed for the five major fish species. The literature on salinity tolerances of the young of 12 species is reviewed.

The relative abundance and times of occurrence of the six major resident and anadromous fish species are discussed in relation to data obtained before and after operation of the CYAP facility. Basic data on relative numbers and weights are presented for the 44 fish species collected in the river.

A list is provided of those marine fish species which may move with the salinity gradient if it were to penetrate further upstream during diversion conditions.

American Shad

The occurrence of adult shad in the Connecticut River is seasonal, and coincides closely with the spring freshet. The importance of freshet conditions to the spawning migration, including location of the river during the approach from the sea; timing of the entry of shad into the river; and various characteristics of the river migration from the mouth to the spawning areas and back to sea are not well defined. In this study an attempt is made to assess the relationship of discharge to these various factors, and the possible impact of alteration of the natural freshet conditions.

Results are reported from sonic tracking techniques conducted in Long Island Sound to track shad in the area of the Connecticut River discharge and to determine factors influencing their sea to freshwater migration. Effects of changes in temperature and flow are examined with regard to catch per unit effort in the commercial fishery, the sport fishery at Enfield, and shad passage at Holyoke Dam. The mortality experienced by a portion of the spawning run and its relationship to temperature are assessed.

Bibliography

A comprehensive search of the literature dealing with the effects of diversion was carried out, resulting in approximately three hundred references, many of which are cited in this report, and listed under Cited References. Those not cited are listed under Selected References.

SUMMARY OF CONCLUSIONS

1. Changes in river temperature due to the diversions under consideration should not exceed 0.61°F under the worst case postulated (i.e. 12,000 cfs at Montague City and 4,000 cfs diversion). Although many biological effects of temperature elevations are well known, in most cases the effects resulting from such a small temperature increment are too small to quantify.

Biological evaluations were made using a 2°F temperature rise in the estuary. The rationale for choosing this temperature rise is twofold. First, biological changes could not be predicted on much less than a 2°F increment of change and secondly, it would be only an academic exercise to try to refine predictions at a smaller increment of change if in fact no significant changes would occur at the 2°F increment. As it turns out, even a 2°F temperature rise would not cause a serious impediment to presently considered diversion plans as far as the ecological balance of the estuary is concerned. Keeping in mind that the calculated temperature rise is less than 1/3 the value used in biological evaluation (.61°F vs. 2°F), the reader is advised of the conservative nature of the biological evaluation that is presented later in this volume and summarized in the following paragraphs.

Among the known biological effects of increased temperature, the following may be expected, but it should be kept in mind that even if deleterious, the small change in temperature will result in too small a magnitude of change to be cause for alarm.

a) Change in the Time and Location of Shad Spawning - Studies have indicated that the ovaries of female shad develop slowly when exposed to temperatures of 55 to 65°F and more rapidly when exposed to the warmer temperatures of 68 to 77°F. This apparently means that shad will tend to hold their eggs longer and migrate further up-river during a cold water spring. This is borne out by observations during May 1967, when cooler than normal temperatures caused spawning to take place in the upper reaches of the study area. In contrast, the warmer temperatures of May 1968 caused spawning to occur further downstream.

Calculations indicate that a 2°F temperature rise in the river water would have caused spawning to occur 3.4 days earlier in 1967 and 3.6 days earlier in 1968. It is postulated that the most severe diversions postulated would have an insignificant effect on shad spawning.

b) Shad Egg Size, Abundance, Development Time, and Mortality - Calculations indicate that a 2°F temperature rise would reduce average egg size from 3.06 mm to 2.84 mm. This

decrease is considered insignificant since it falls well within the normal range of egg sizes (2.1 to 3.1 mm). Available data does not lend itself to a correlation of egg abundance to temperature or flow.

A definite correlation between egg development time and water temperature has been observed; however, a 2°F temperature rise is expected to cause eggs to develop only 17 hours earlier. This would still put the average development time well within the naturally occurring limits of development time. High water conditions and widely fluctuating temperatures are considered the chief cause of egg mortality and since diversion will not worsen either of these conditions, no increased egg mortality is expected.

Shad spawning success in general will not be greatly influenced by the postulated diversions. After diversion, temperatures would still remain well within normally occurring variations and since spawning occurs well above the salinity intrusion, any changes in salinity patterns will not affect spawning.

c) Effects on Survival of Eggs and Larvae of Shad and Resident Fish Species - Temperature rise and salinity changes that would be brought about by the postulated diversions are not expected to affect eggs and larval survival, development or growth of any of the fish species tested.

d) Adult Fish Populations - Massive blueback herring kills were reported in 1965 to 1967, however, these occurred during the summer months as dissolved oxygen fell below 4.3 mg/l and temperatures rose above 77°F. Since these conditions occurred well beyond the period of contemplated diversion, no worsening of an already bad situation is to be expected. Some adult fish could feel an effect of the diversion as a result of shifting (in time) of the availability of a food supply. Food generally becomes available as temperatures exceed 40°F. A 2°F temperature rise would have caused this 40°F temperature to be reached 4.3 and 6.8 days earlier in 1969 and 1970 respectively. Since some adult fish winter in coves and do not move out into the river until temperatures reach 40°F in the coves, they may arrive in the river up to a week after the food supply begins to develop. This assumes that water temperature in the coves would not be influenced by the 2°F temperature rise in the river. More information is needed in this area to draw any definite conclusions, but no problem of significant proportions is anticipated.

e) Homing Ability and Timing of Arrival of Adult Shad - Adult shad appear to be able to home even during extreme low flows. Diversion will not reduce flows during these extreme low

flow conditions so it is logical to assume that the shad's homing will not be impaired by diversion of freshet water. Historically it has been found that shad tend to enter the estuary when temperatures reach 40° to 43°F. Diversion would cause these temperatures to be reached somewhat earlier, but no problem is anticipated.

f) Microbiological Population - Because of the paucity of data in some critical areas of basic biology deemed pertinent considering the postulated diversions, no absolute predictions can be made regarding the ultimate fate of microorganisms in the estuary. Since the temperature and salinity rises are so small (<2°F and a few mg/l) at any given point and since these changes develop over a period of time, no significant qualitative or quantitative alterations of bacterial populations are to be expected in the short run (a few years). Beyond this span any prediction would be speculative.

g) Invertebrates - 48 recurring species of invertebrates have been identified in 60 months of sampling. Of these, four species are dominant. In their order of abundance are Limnodrilus hoffmeisteri, a worm; Psectrotanypus and Cryptochironomus, flies; and Pisidium, the fingernail clam. A 2°F temperature increase can be expected to increase the metabolic activity and probably advance sexual maturity slightly in each of the above species. However, since the postulated diversions will not be made during summer low-flow-high-temperature situations, these species are not put under any undue stress. Temperatures after postulated diversion will still be well within the limits of naturally occurring variation and only minimal adverse effects are to be expected.

2. Freshet conditions should continue throughout the estuary if no diversion takes place when flows are less than 17,000 cfs at Montague City. The duration of freshet will be shortened by 2 to 4 days at both the onset and cessation of freshet in a normal year with diversion. If 12,000 cfs were considered as a control flow, then freshet conditions would be shortened by 3 to 9 days at both the onset and cessation of freshet in a normal year.

3. At a 12,000 cfs controlling flow at Montague City, minor reversals of current may occur in the lower estuary. These should not be sufficient to cause a biologically significant intrusion of saltwater from Long Island Sound.

4. Under either controlling flow regime, changes in salinity distribution will be too small to have measurable biological effects.

RECOMMENDATIONS FOR FURTHER STUDIES

1. Until considerably more work is done to fully delineate the physical and biological parameters of the river, the controlling flow for diversion should be considered at no less than 17,000 cfs at Montague City.

2. Research in connection with the preparation of this report revealed the extreme paucity of relevant data, both physical and biological. Rational decisions involving alterations of the natural regimen of the river are difficult in the absence of such data. A program should be undertaken without delay to provide the information which will be required as future demands arise for new uses of the river.

3. Specifically, in the biological field the following are among the most pressing needs.

   a. The biology of the lower river at and below the freshwater-saltwater interface is little known. A complete biological inventory is essential if the possibility exists of future alterations which would affect this area.

   b. While some work is presently underway, there is much to be learned about the homing mechanism of the shad, and the effects of temperature or of flow volume and velocity on its spawning migration. The same parameters may well effect the population dynamics of other fish and lower species in the food chain.

   c. If the current attempt to restore the Atlantic salmon to the Connecticut River is successful, the requirements of this important species must be intensively studied to safeguard its continuing existence.

4. A three part program for delineating the physical and chemical characteristics of the river is required to provide information needed not only for future decisions, but to assess the effects of alterations presently in the planning stage.

   a. A continuous *in situ* monitoring system should be established to measure such common parameters as temperature, dissolved oxygen, conductivity, and flow velocity. The technology for such a system is readily available, and considerably less expensive than it was even a few years ago.

   b. An hydraulic model of the river should be constructed,

using the data from the monitoring system for calibration.

c. Data from the monitoring system and the hydraulic model would make possible the design and calibration of a mathematical model. Such a model would make it possible to test the effects of proposed changes in river utilization at a very reasonable cost. Attempts to mathematically model the river in the absence of real physical and chemical data have not been satisfactory.

HYDROLOGICAL EFFECTS OF DIVERSIONS

Flow Relationships Between Montague City, Massachusetts and Bodkin Rock, Connecticut

In order to assess the effects on the Connecticut River Estuary of diversions at Northfield, Massachusetts it is first necessary to establish the relationship between flows at or near Northfield and flows in the estuary. The United States Geological Survey (USGS) has maintained a gauging station at Montague City, Massachusetts since 1904. Montague City is approximately ten miles below the point of proposed diversion, and as noted in the Introduction, the proposed diversions are to be limited by either 17,000 or 12,000 cfs discharge at Montague City. It therefore seems reasonable to use Montague City as the reference point for upstream flows. Unfortunately, data for flows in the Estuary, at Bodkin Rock, are only available for part of water year 1966, all of water year 1967, and part of water year 1968 (USGS 1967, 1969, 1971a). It should be noted that the USGS data for Bodkin Rock is in the form of daily flows, upstream and downstream. Conversion of these flows to discharges, by substracting upstream flows from downstream flows, yield acceptably accurate results, but the daily values occasionally exhibit the extreme variability associated with small differences between large numbers. The USGS gauging station at Thompsonville, Connecticut, just above the Enfield Dam is useful as an intermediate point between Montague City and the Estuary.

For the purpose of developing the mathematical relationship between discharges at Montague City and Bodkin Rock, single and multiple linear regressions were run on data from Montague City (USGS 1967a, 1968a, 1969a), and Thompsonville and Bodkin Rock (USGS 1967, 1968, 1969), for the 35 months in which USGS data was available for all three points. The regressions were run using the standard routines of the IBM Scientific Subroutine package for the 1130 Computing System. These routines are based on Ostle (1963).

Each of the ten regressions yielded results showing good correlation and a high degree of statistical significance. However, mean monthly discharges yielded more significant results than either high or low discharges, and the single regressions from station to station showed a higher degree of correlation than the multiple regression of Montague City and Thompsonville on Bodkin Rock. A summary of these regressions is presented in Table 1.

RESULTS OF LINEAR REGRESSIONS

REGRESSION	CORRELATION	REGRESSION COEF.	INTERCEPT	F
MC on BR H	.92431	1.10080	666.31262	193.578
M	.97848	1.30222	-1079.21118	742.334
L	.92620	1.19147	1058.3723	199.143
TV on BR H	.94270	1.02937	- 140.30862	263.479
M	.98684	1.13952	-1257.7916	1229.910
L	.94441	1.15133	- 882.5294	272.302
MC, TV on BR H	.92431	-1.58246	- 337.23443	155.513
	.94270	2.47285		
	.95221			
M	.97848	-1.65129	-1268.52173	838.182
	.98684	2.56877		
	.99059			
L	.92620	.30083	- 493.26861	137.749
	.94441	.87693		
	.94653			
MC_m on TV_m	.99758	1.14976	73.83399	6813.553

(1) $TV_m = 1.14976\ MC_m + 73.834$

(2) $BR_m = 1.13952\ TV_m - 1257.79$

(3) $BR_m = 1.13952(1.14976\ MC_m + 73.834) - 1257.79$

$= 1.31017\ MC_m - 1173.656$

Table 1

The mean discharge regressions yield the following relationships:

$$TV_m = 1.14976\ MC_m + 73.834 \quad (1)$$

$$BR_m = 1.13952\ TV_m - 1257.79 \quad (2)$$

where TV_m = mean monthly discharge at Thompsonville, MC_m = mean monthly discharge at Montague City, and BR_m = mean monthly discharge at Bodkin Rock.

Substituting for TV_m in (2) yields:

$$BR_m = 1.31017\ MC_m - 1173.656 \quad (3)$$

Using the above relationship (3), discharges for Bodkin Rock were calculated based upon actual discharges at Montague City, and these results are compared with the actual discharges at Bodkin Rock in Figure 7. The results are in general agreement. An analysis of variance yields a correlation coefficient of .9785 and an F value of 742.3, with a p. of $< .05$. Confidence in the validity of the equation is further enhanced by its close agreement to the ratio of the drainage areas of the two gauging stations, which is 1.38 to 1. Actual discharges at Montague City (USGS 1971, 1970a, 1969a, 1968a, 1967a) are presented in Figure 8, and calculated discharges at Bodkin Rock, based upon the Montague City flows, are presented in Figure 9, each for the period from July 1966 through November 1970.

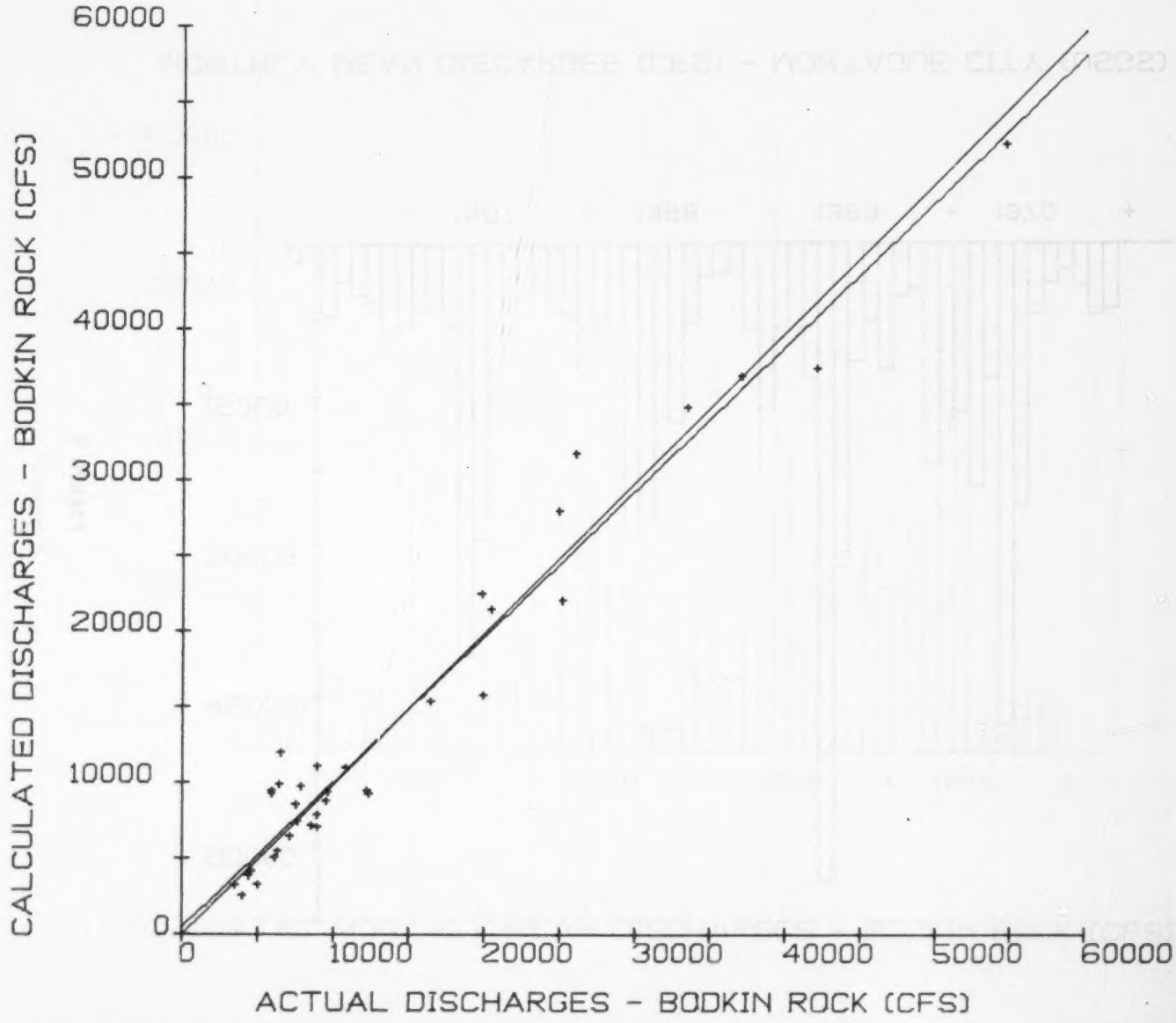
60000
50000
40000
30000
20000
10000
0
CALCULATED DISCHARGES - BODKIN ROCK (CFS)
0
10000
20000
30000
40000
50000
60000
ACTUAL DISCHARGES - BODKIN ROCK (CFS)

Figure 7

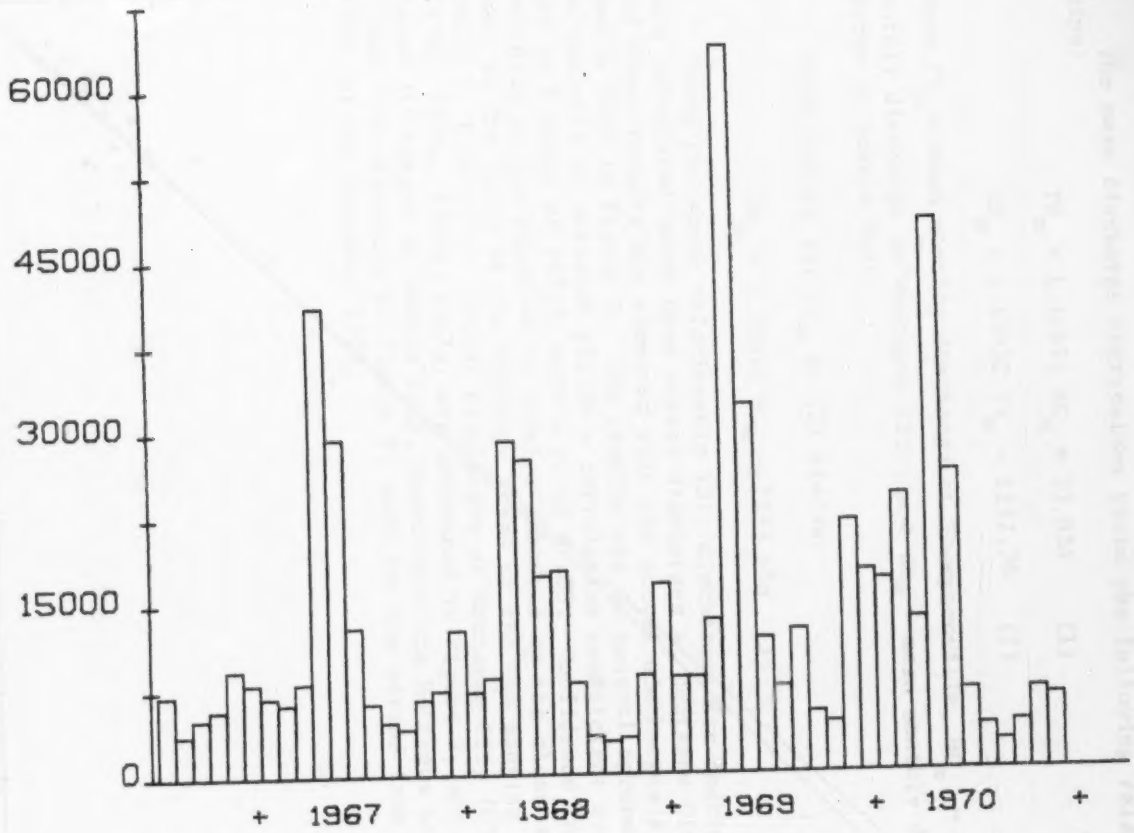

Figure 8

MONTHLY MEAN DISCARGES (CFS) - MONTAGUE CITY (USGS)

Figure 9

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Effects of Diversion on Temperature Regimen

In order to calculate the changes in temperature caused by varying diversions, the following assumptions are necessary:

1. The presently existing heat load will remain unchanged.
2. Complete mixing of heated effluents occurs within a reasonable distance from the outfalls.
3. There is no significant gain or loss of heat from the water to either earth or air.

The first assumption is clearly unreasonable in light of existing plans and projections for expansion of steam generating capacity and other processes requiring large amounts of cooling water. As such additional sources of heat materialize, their effects on the temperature regimen should be studied in relation to the various diversions.

The second assumption is borne out by previous work on warm water effluents. It has been shown that the warm water effluent from the CYAP plant becomes thoroughly mixed with the confluent river water within approximately two miles of the outfall at most seasons of the year (Boyd). Infrared thermometry shows highly localized temperature peaks in the vicinity of other thermal effluents, indicating that they too mix within a relatively short distance (pers. comm. R. A. Jones). Furthermore, since the diversions are to be limited to freshet conditions, mixing will be aided by the high velocities and turbulence which are characteristic of freshet flow. Indeed, during freshet conditions the thermal structures associated with the CYAP outfall are found to disappear (Boyd).

The third assumption seems reasonable, at least during the freshet season, since during this period of the year a net rise in temperature occurs. Heat losses to the earth are minimal inasmuch as the temperature differential between earth and water is at or near its annual minimum at the onset of freshet, and does not increase greatly by the end of freshet.

With one exception, the heat inputs used for the mixing calculation are in accordance with values supplied by the Corps of Engineers. In the case of the CYAP plant the values have been adjusted from an effluent rate of 814 cubic feet per second with a temperature rise of 20.4°F as stated by the Corps of Engineers to an effluent rate of 830 cfs and a temperature rise of 22.8°F in accordance with more current information (Merriman et al, 1970). These data, and the thermal load resulting from the described effluents are presented in Table 2. The thermal loading from the Vermont Yankee Atomic Power Company's plant at Vernon, Vermont is

EXISTING THERMAL LOAD

SOURCE	EFFLUENT RATE (CFS)	TEMP. RISE (F.)	LB./SEC	BTU/SEC	
Above Enfield					
Mount Tom	201	11.8	12,542	147,996	
Riverside	66.5	11.8	4,150	48,970	
Holyoke	41	12.0	2,558	30,696	
W. Springfield	249	16.1	15,538	250,162	
State Street	80	11.8	4,992	58,906	
S. Meadow	523	10.4	32,635	339,404	876,134
Estuary					
Maromas	570	13.0	35,568	462,384	
CYAP	830	22.8	51,792	1,180,858	1,643.242
				TOTAL	2,519,376

Table 2

not included in these calculations, since it is above the point of diversion, and the anticipated load from this source would not change the conclusions of this study.

Inasmuch as there are two large heat sources located near the middle of the Connecticut River Estuary, the mixing calculation has been divided so as to cover the upper reach of the estuary, above Maromas, and the lower reach of the estuary, below the CYAP plant. Discharges at Thompsonville and Bodkin Rock are calculated from the given discharges at Montague City by means of equations (1) and (3) above. For the upper estuary temperature elevation calculation, Thompsonville discharges are used, while the lower estuary values are based upon Bodkin Rock calculated discharges. Results of these calculations are given in Table 3. Certain minor thermal loads have been ignored, largely because of the near impossibility of obtaining accurate data, but also because of their extremely small magnitude. No attempt has been made to account for any difference in solar heating as a result of the various diversions, since specific data for the Connecticut River are not available. A theoretical approach could be used to indicate the magnitude of such changes, however at the presently postulated levels of diversion it is not believed that the results would be of any great significance. In the event that larger diversions are proposed at any time, or if diversions are proposed which will reduce the minimum flow at Montague City below the presently postulated 12,000 cfs, such studies should be pursued.

Essex Marine Laboratory has been monitoring river temperatures at five stations in the vicinity of the CYAP plant for approximately six years, as part of a long term study to assess the effects of this plant on the Connecticut River. Figure 10 gives the locations of these stations. Monthly high, mean and low temperature for the period from July 1966 through November 1970 have been taken from the data gathered for this study, and are presented in Figures 11 and 12 for Stations 3 and 5 respectively. The breaks in these plots represent periods in which the monitoring stations were removed because of heavy river ice.

Effects of Diversions on Freshet Conditions

Freshet, as defined for the purposes of this study, occurs at Bodkin Rock when a discharge of approximately 22,000 cfs is attained, and persists until the discharge falls somewhat below this rate. 22,000 cfs at Bodkin Rock is equivalent to 17,698 cfs at Montague City, so it is apparent that diversions at Northfield which do not reduce Montague City discharges below 17,000 cubic feet per second will not prevent freshet conditions in the lower estuary. On the other hand, flows of 12,000 cfs at Montague City,

TWO REAC MIXING CALCULATION

TEMPERATURE ELEVATIONS (DEG. F.) ABOVE MAHOMAS (UPPER VALUE) AND BELOW CYAP (LOWER VALUE). FOR STATED DIVERSIONS AT NORTHFIELD. HEAT LOADS BASED ON USACE MEMO NO. 3. FLOWS CALCULATED BY LINEAR REGRESSION EQUATIONS.

FLOW AT MONTAGUE CITY	CALCULATED FLOWS AT THOMPSONVILLE	CALCULATED FLOWS AT BODKIN ROCK	DIVERSIONS AT NORTHFIELD (CFS) 0	600	800	1000	1600	2000	3000	4000
100000.	115049.	129843.	0.12 0.31	0.12 0.31	0.12 0.31	0.12 0.31	0.12 0.31	0.12 0.32	0.13 0.32	0.13 0.32
90000.	103552.	116741.	0.14 0.35	0.14 0.35	0.14 0.35	0.14 0.35	0.14 0.35	0.14 0.35	0.14 0.35	0.14 0.36
80000.	92054.	103639.	0.15 0.39	0.15 0.39	0.15 0.39	0.15 0.39	0.16 0.40	0.16 0.40	0.16 0.40	0.16 0.41
70000.	80557.	90538.	0.17 0.45	0.18 0.45	0.18 0.45	0.18 0.45	0.18 0.45	0.18 0.46	0.18 0.46	0.18 0.47
60000.	69059.	77436.	0.20 0.52	0.21 0.53	0.21 0.53	0.21 0.53	0.21 0.53	0.21 0.54	0.21 0.54	0.22 0.55
50000.	57561.	64334.	0.24 0.63	0.25 0.63	0.25 0.64	0.25 0.64	0.25 0.64	0.25 0.65	0.26 0.66	0.26 0.67
40000.	46064.	51233.	0.30 0.79	0.31 0.80	0.31 0.80	0.31 0.80	0.32 0.81	0.32 0.82	0.33 0.84	0.33 0.85
30000.	34566.	38131.	0.41 1.06	0.41 1.08	0.42 1.08	0.42 1.09	0.43 1.11	0.43 1.12	0.44 1.15	0.46 1.18
20000.	23069.	25029.	0.61 1.61	0.62 1.65	0.63 1.67	0.64 1.68	0.65 1.72	0.67 1.75	0.70 1.83	0.74 1.92
19000.	21919.	23719.	0.64 1.70	0.66 1.75	0.66 1.76	0.67 1.78	0.69 1.83	0.70 1.86	0.74 1.95	0.78 2.05
18000.	20769.	22409.	0.68 1.80	0.70 1.85	0.70 1.87	0.71 1.89	0.73 1.94	0.75 1.98	0.79 2.08	0.84 2.19
17000.	19619.	21099.	0.72 1.91	0.74 1.97	0.75 1.99	0.75 2.01	0.78 2.07	0.80 2.11	0.84 2.23	0.90 2.36
16000.	18469.	19789.	0.76 2.04	0.79 2.10	0.79 2.13	0.80 2.15	0.83 2.22	0.85 2.27	0.91 2.43	0.97 2.56
15000.	17320.	18478.	0.81 2.18	0.84 2.26	0.85 2.28	0.86 2.31	0.89 2.39	0.92 2.45	0.98 2.61	1.05 2.79
14000.	16170.	17168.	0.87 2.35	0.90 2.44	0.91 2.47	0.93 2.50	0.96 2.59	0.99 2.66	1.07 2.85	1.15 3.07
13000.	15020.	15858.	0.93 2.55	0.97 2.65	0.99 2.68	1.00 2.72	1.05 2.83	1.08 2.91	1.17 3.14	1.27 3.40
12000.	13870.	14548.	1.01 2.78	1.06 2.89	1.07 2.94	1.09 2.98	1.14 3.12	1.18 3.22	1.29 3.52	1.40 3.83

Table 3
-25-

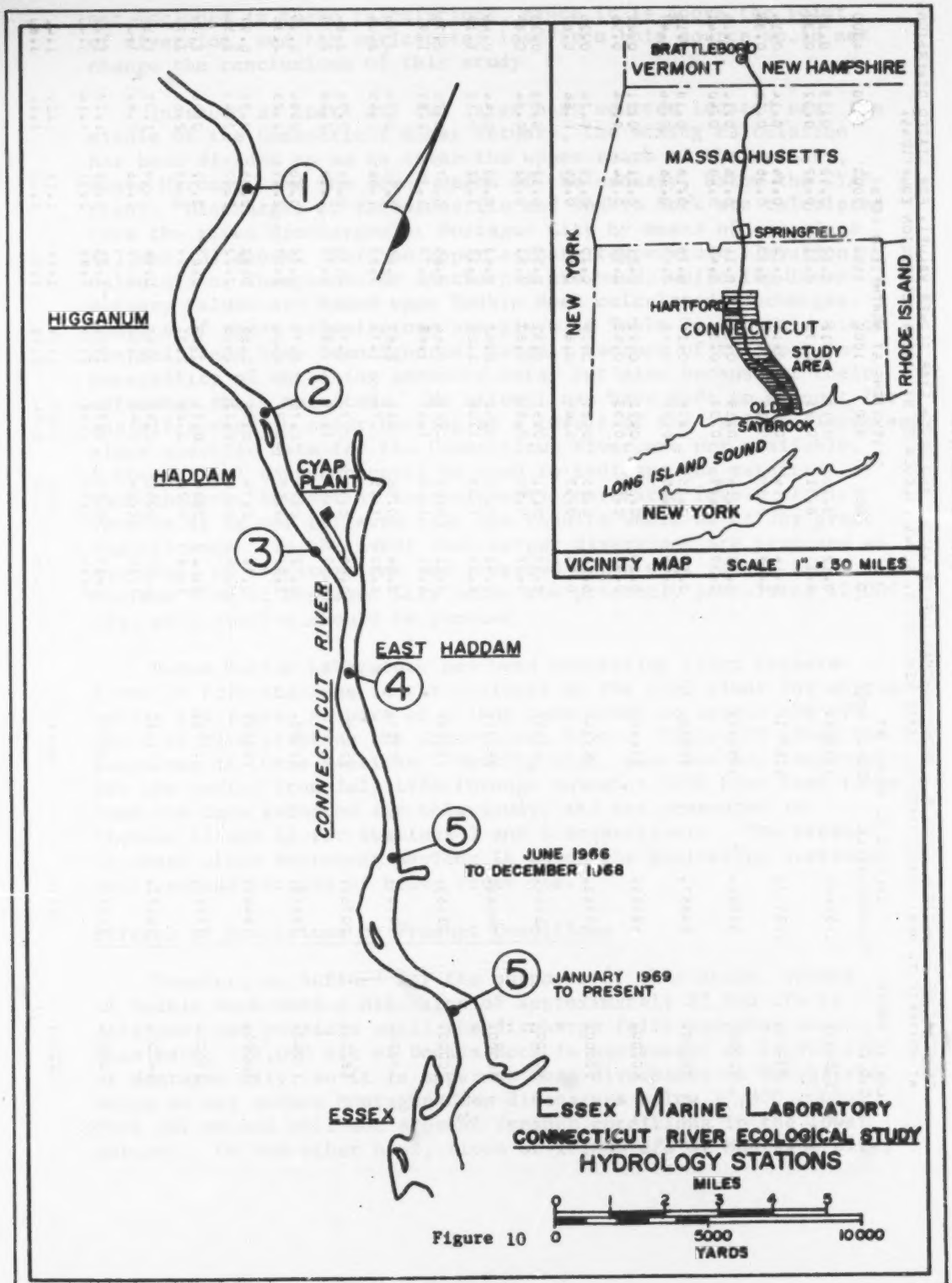
BRATTLEBORO
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
SPRINGFIELD
NEW YORK
HARTFORD
CONNECTICUT
STUDY AREA
RHODE ISLAND
OLD SAYBROOK
LONG ISLAND SOUND
NEW YORK
VICINITY MAP SCALE 1" = 50 MILES
HIGGANUM
HADDAM
CYAP PLANT
EAST HADDAM
CONNECTICUT RIVER
JUNE 1966 TO DECEMBER 1968
JANUARY 1969 TO PRESENT
ESSEX
ESSEX MARINE LABORATORY
CONNECTICUT RIVER ECOLOGICAL STUDY
HYDROLOGY STATIONS
MILES
0 1 2 3 4 5
0 5000 10000
YARDS

Figure 10

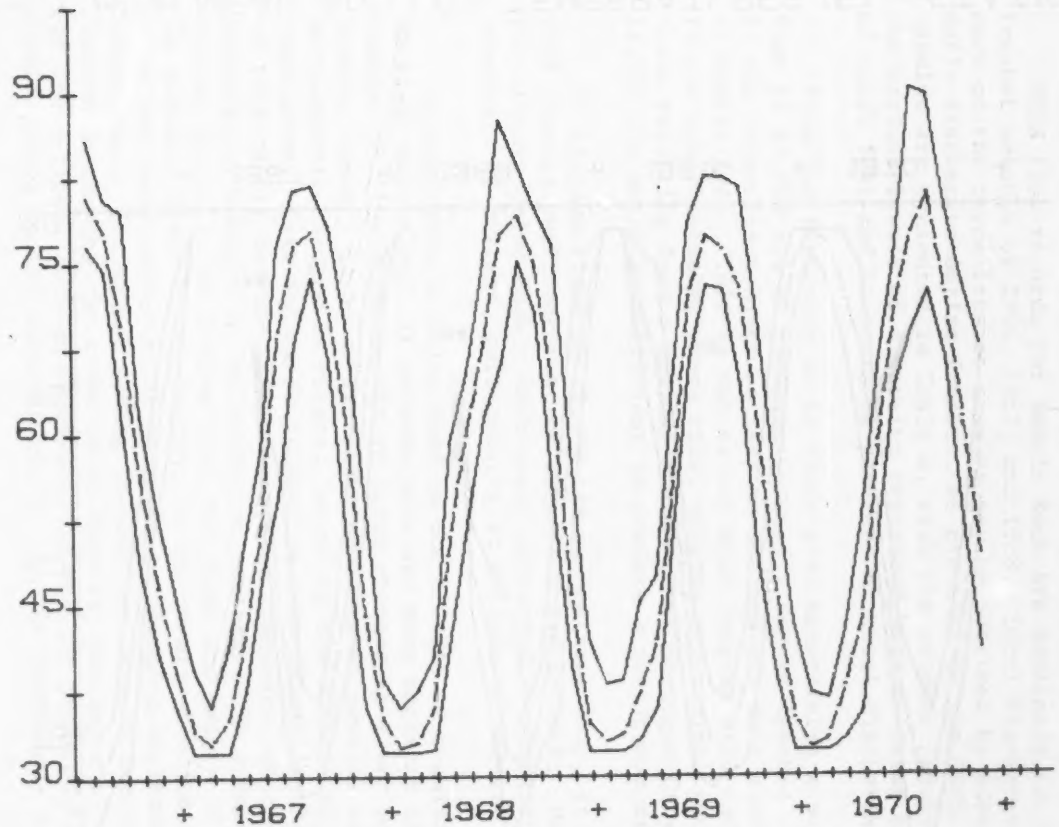

Figure 11

MONTHLY HIGH MEAN AND LOW TEMPERATURES (F) - STATION 3

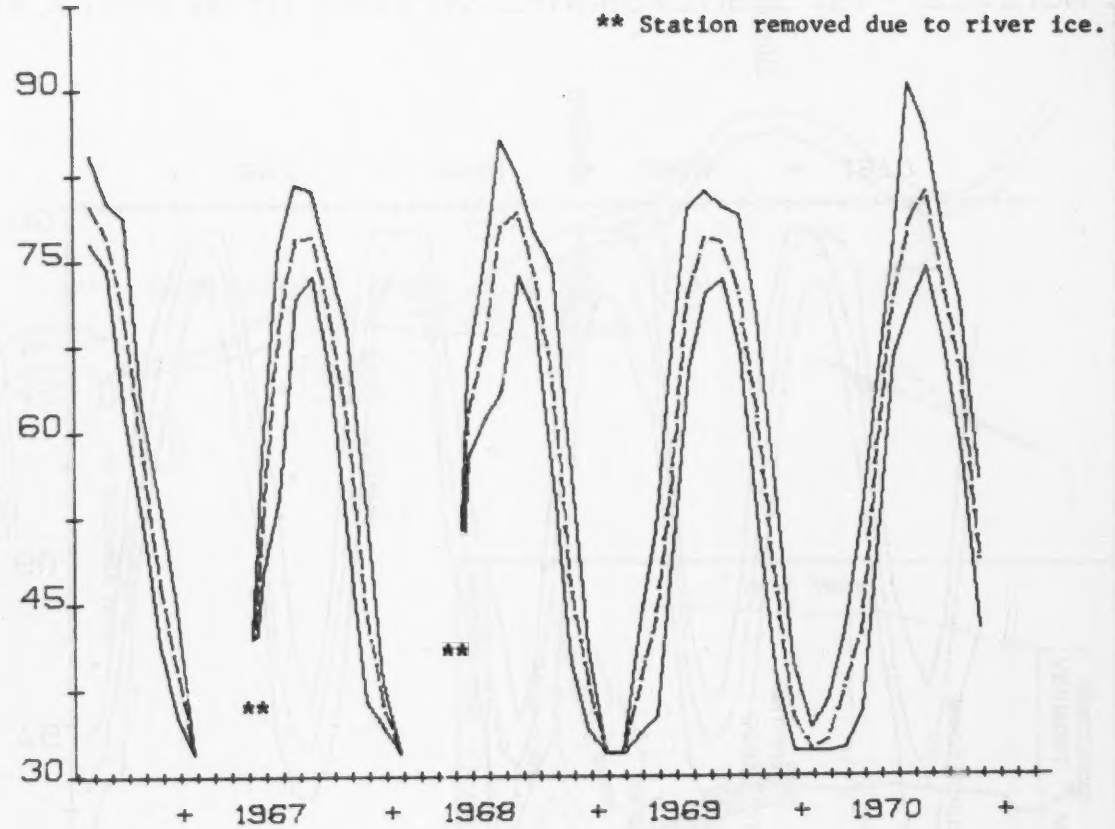

Figure 12

MONTHLY HIGH MEAN AND LOW TEMPERATURES (F) - STATION 5

equivalent to only 14,549 cfs at Bodkin Rock would not produce freshet flows at this level.

USGS flow records for Bodkin Rock are available for the freshet seasons of 1966, 1967, and 1968. Total discharges during each of the three freshet seasons may be obtained by summing the daily discharges during freshet, as provided by the USGS. These results are presented in Table 4, with the volumes required for the various levels of diversion expressed both in terms of millions of cubic feet and in terms of per cent of total discharge.

From the foregoing it is clear that maintaining a minimum flow of 12,000 cfs at Montague City will remove freshet conditions in the Connecticut River Estuary as defined for this study, i.e. at Bodkin Rock. This is not to say that freshet will not occur in the upper Estuary, where tidal effects are minimal and the flows resulting from a minimum discharge at Montague City of 12,000 cfs would be sufficient to produce a continuous discharge.

At minimum flows of 17,000 cfs at Montague City, it appears that freshet would occur at or very near Bodkin Rock. However, the estuary below Bodkin Rock would undoubtedly experience daily reversals of current, particularly at periods of extreme tides.

As more work is being done on the effects of regulated flows on river morphology, it becomes more and more apparent that small changes in flow often result in large changes in river morphology. Blench (unpub.) gives an excellent overview of several causes of morphometric changes in rivers, including the effects of flow regulation. This matter is treated in more detail in the section of this report dealing with the benthic community, which is most affected by changes in sedimentation patterns. At a more superficial level, it is obvious that the shape and nature of the Connecticut River at any instant is the result of adjustments made over many centuries in response to changing environmental conditions. The annual spring freshet has been an important factor in shaping the river as we know it, and major alterations of these flows, such as diversions beyond the presently postulated limits, will be reflected in changes in the morphology of the river.

Figure 39 (page 104) portrays daily discharges at Thompsonville for five successive seasons, and shows that both the onset and cessation of freshet are sudden. For this reason, whether the controlling flow is set at either 12,000 or 17,000 cfs, it is unlikely that the postulated diversions will affect the length of the freshet season by more than a few days at either end. While this change may have some biological significance, as discussed further on in this report, it seems unlikely that it would have any appreciable effect on the hydrological regimen of the estuary.

Table 4

VARIOUS DIVERSIONS AS PERCENT OF FRESHET DISCHARGE

	1966		1967		1968	
Duration of freshet (days)	86		93		102	
Total discharge (10^6 ft^3)	181,354		311,413		302,211	
	10^6 ft^3	%	10^6 ft^3	%	10^6 ft^3	%
Total diversion at 600 cfs	4,528	2.3	4,821	1.5	5,288	1.7
800	5,944	3.3	6,428	2.1	7,050	2.3
1000	7,430	4.1	8,035	2.6	8,813	2.9
1600	11,889	6.6	12,856	4.1	14,100	4.7
2000	14,860	8.2	16,070	5.2	17,626	5.8
3000	22,291	12.3	24,106	7.7	26,438	8.7
4000	29,722	16.4	32,141	10.3	35,251	11.7

Effects of Diversion on Salinity

Essex Marine Laboratory's five monitoring stations have recorded conductivity, among other parameters, since July 1966. The purpose of these conductivity measurements is to delineate the movements of the salinity gradient in the vicinity of the CYAP plant. Monthly high, mean and low conductivity values for Station 5 are given in Figure 13 for the period from July 1966 through November 1970. Station 5 was located on the east bank of the river, 10.3 miles above the mouth until December 1969 when it was relocated to the west bank of the river, 8.0 miles above the mouth. Station 5 was operated seasonally until March 1969, when it was converted to a year-around station.

The results of this work show that the main body of salinity lies below the Haddam Bridge (13.4 miles from the river mouth) for most of the year. Only during seasons of extreme low flow does it approach the CYAP plant, and then only during periods of extreme tidal ranges. Obviously, during freshet conditions any salinity is restricted to an area within a very short distance from the mouth of the river.

Unfortunately, the Essex Marine Laboratory stations do not yield any data for that part of the estuary lying within the first eight miles of the river. Meade, however, presents an excellent description of the response of the salinity front to varying rates of discharge. His data are summarized in Table 5, showing the position of various levels of chloride concentrations in terms of their distance from the mouth of the river. Meade also describes the vertical distribution of chlorides, indicating that the gradient steepens with increasing flows, and flattens with decreasing flows.

Meade's work shows that chloride concentrations in excess of one part per thousand did not exist above river mile 2.4 with a discharge at Thompsonville of 17,798 cfs on the preceding day. This indicates that with a control flow of 17,000 cfs at Montague City, equivalent to more than 22,000 cfs at Saybrook, there would be little or no change in the position of the freshwater-to-saltwater gradient. Even with the Thompsonville discharge reduced to 9,322 cfs, Meade shows no concentrations of one part per thousand or more at river mile 5.8. It is obvious that the interface would move upstream with this reduction in flow, but from Meade's work it appears that even at a controlling flow of 12,000 cfs at Montague City, the interface would not move above river mile 5.8.

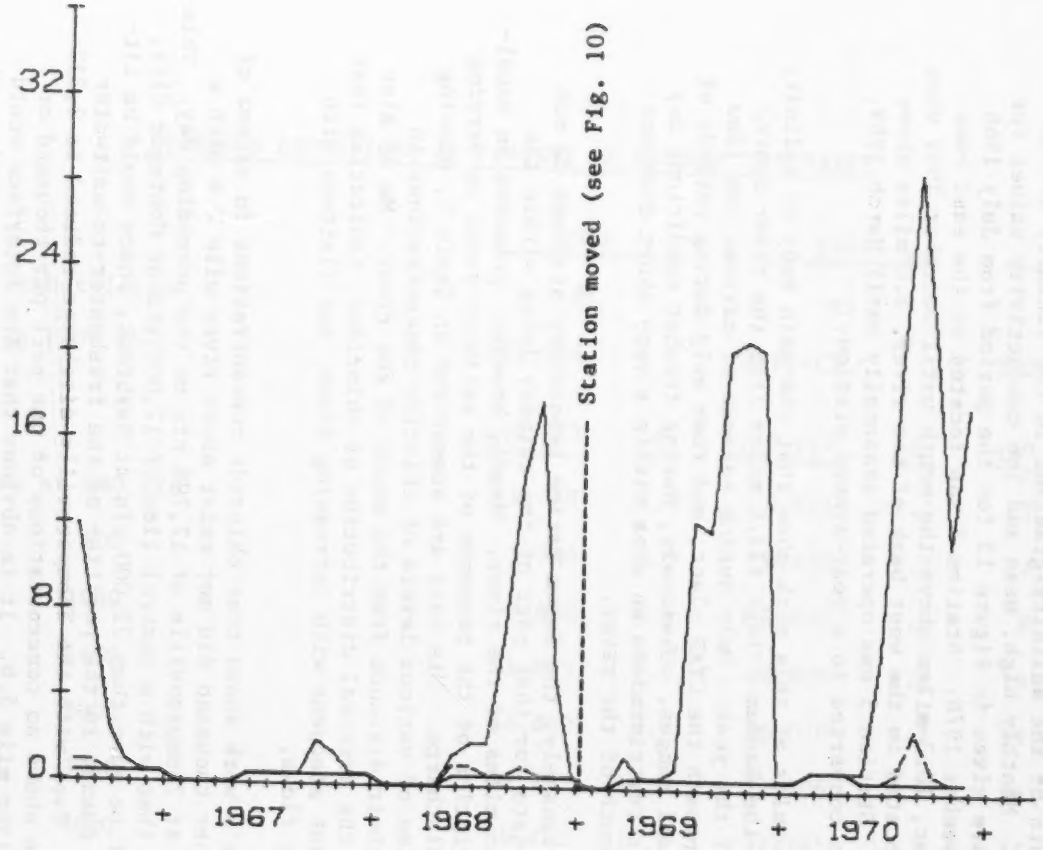

Figure 13

MONTHLY HIGH MEAN AND LOW CONDUCTIVITY (MMHOS-CM) - STA. 5

Table 5

Chloride Concentrations near Mouth of Connecticut River

Date	Discharge at Thompsonville (cfs)	Surface Chloride Concentrations (ppm)					
		0.01	1.0	2.0	4.0	8.0	10.0
		Distance (mi.) from Mouth of River					
27 Aug 1935	2,013	12.5	8.3	7.6	5.6	4.0	2.4
29 Sep 1935	5,933	10.7	7.8	7.2	5.4	3.1	-
18 Aug 1935	7,698	9.7	7.4	5.7	4.2	2.0	-
25 Jul 1935	9,322	5.8	-	-	-	-	-
12 Jun 1935	17,798	5.6	-	-	-	-	-
13 Apr 1937	32,030	-	-	-	-	-	-

Providing that freshet conditions are maintained during periods of diversion, saline water will continue to be restricted to the area near the mouth of the river. If diversions are large enough to permit reversals of current in the lower estuary, the salinity front will advance upriver, reaching positions corresponding to the various flows as shown by Meade (1966).

Conclusions

1. Temperature elevations at the highest postulated diversion will be approximately 0.61°F.

2. Maintenance of 17,000 cfs at Montague City will suffice to produce freshet conditions in the estuary - 12,000 cfs will not.

3. If freshet conditions are maintained, there will be no appreciable change in the salinity distribution.

4. If freshet conditions are not maintained, the salinity gradient will migrate in response to changes in discharge rate.

POSSIBLE EFFECTS OF DIVERSION ON THE CONNECTICUT RIVER BENTHIC FAUNA

This report describes major trends of animal populations, flow volumes, temperatures and sediment compositions in terms of mean monthly values for 60 months from January 1966 to December 1970. From these data basic relationships are described from which the effect of diversion of water further upstream (Northfield, Mass.) are considered. The original data is the product of research funded by Connecticut Yankee Atomic Power Company through the Essex Marine Laboratory.

Seventeen stations were selected on the Connecticut River covering an 8-mile stretch (Figure 14). The original choice of stations was based on the predicted thermal discharge patterns. Stations were located along a decreasing heat gradient.

Core and grab samples were taken from the river bottom for grain size analysis.

Generally, 2 to 4 van Veen samples were taken from each station, depending on the species complexity. The sampling interval was about two weeks. In the laboratory the organisms were washed from the sediment and sorted to species. Laboratory analysis consisted of identification, enumeration, and wet and dry weights.

Throughout the 60 months of sampling, 48 reoccurring species of invertebrates have been identified. Of this group four organisms have been dominant. Three main phyla are represented: Annelids with an oligochate, Limnodrilus hoffmeisteri; Arthropoda, insects, represented by Psectrotanypus and Cryptochironomus, and Mollusca, are dominated by the genus Pisidium.

Limnodrilus hoffmeisteri

Limnodrilus hoffmeisteri was the most abundant organism for all stations at nearly all times of the year. At Station 2, peaks were seen during early summer months, June in 1966 and 1967. The water intake at CYAP removed the population (all species) from June of 1968 through March of 1970. During refueling, April 22 to June 5, 1970 and through August, the populations reoccurred in the proximity of the intake area (Figure 15).

The substrate around Station 2 was predominantly sand with a silt layer of several centimeters. An area was dredged out of the river bottom to a depth of 18 ft to the base of the intake weir. Coarse sand of 2.0 mm in diameter remained. It is presumed that the velocity of water going into CYAP is high enough to keep

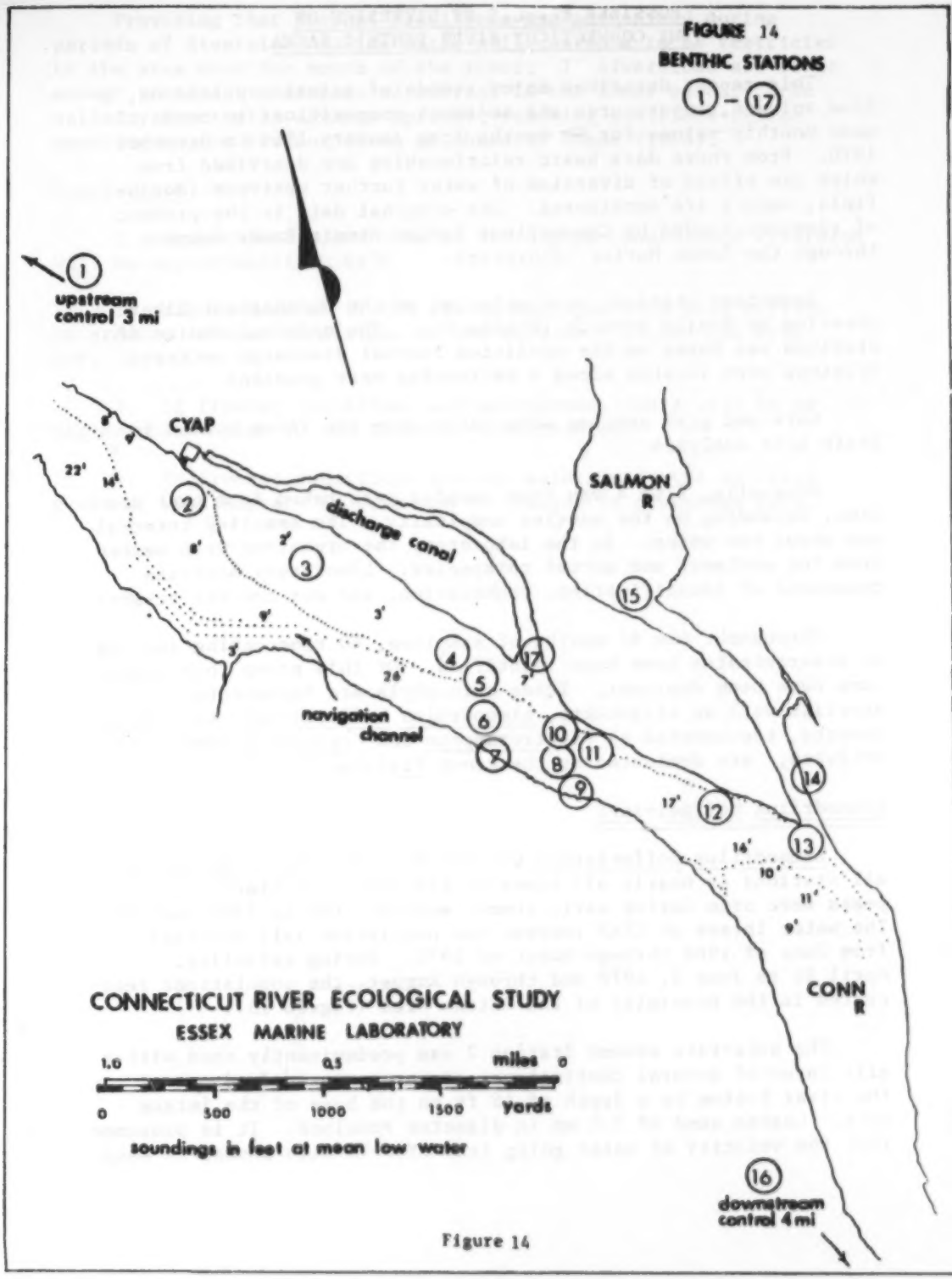
FIGURE 14
BENTHIC STATIONS
1 – 17
1
upstream
control 3 mi
CYAP
discharge canal
SALMON
R
navigation
channel
CONN
R
16
downstream
control 4 mi
CONNECTICUT RIVER ECOLOGICAL STUDY
ESSEX MARINE LABORATORY
1.0
0.5
miles
0
0
500
1000
1500
yards
soundings in feet at mean low water

Figure 14

LIMNODRILUS HOFFMEISTERI

TOTAL NO. M2

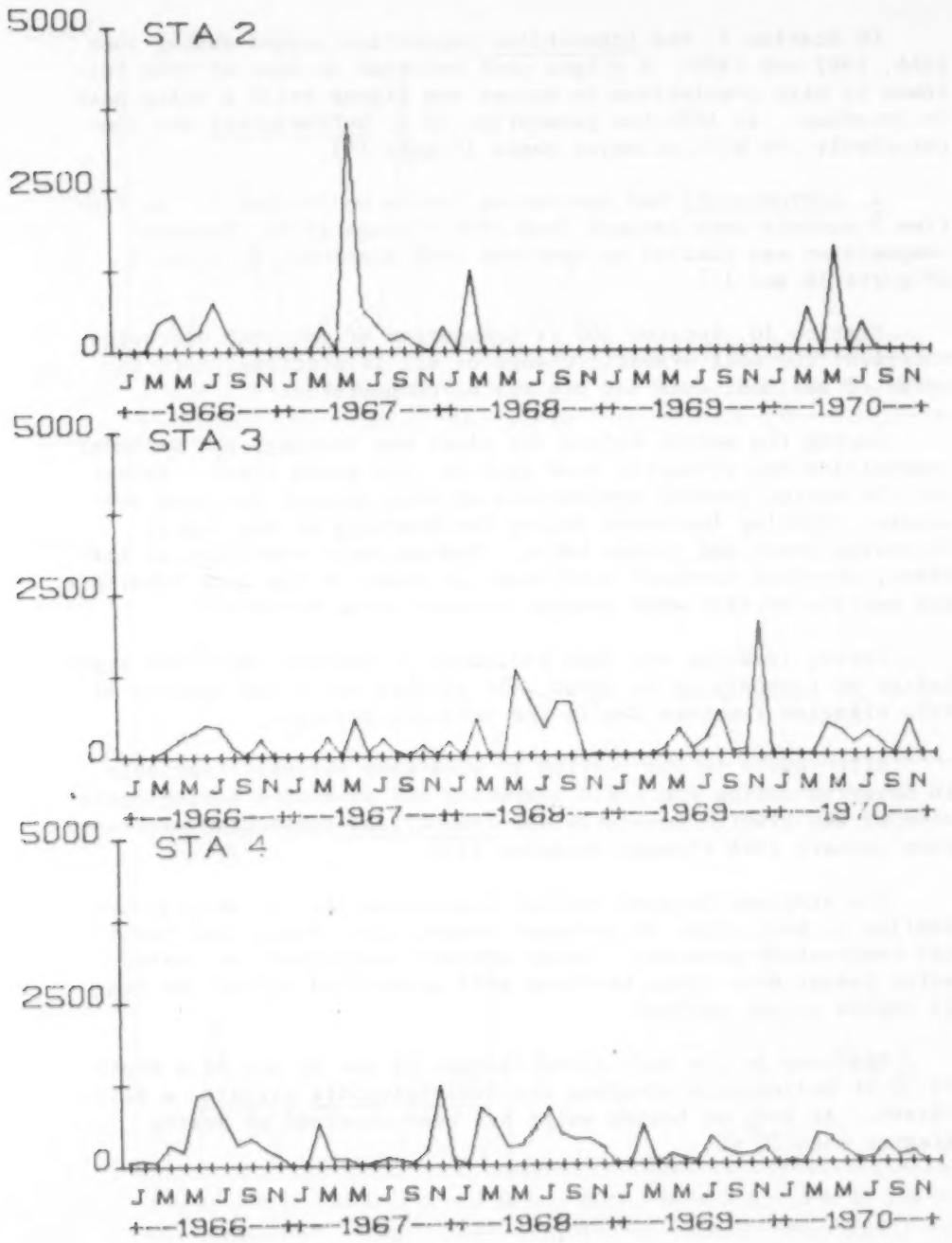
5000
STA 2
2500
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
5000
STA 3
2500
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
5000
STA 4
2500
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970

Figure 15

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the 0.044 silt from being redeposited.

No heated effluent was observed in the bottom waters overlying Station 2, although recirculation of the effluent was common.

On Station 3, the Limnodrilus population peaked during June 1966, 1967 and 1968. A slight peak occurred in June of 1969 followed by high populations in August and higher still a third peak in December. In 1970 the population of L. hoffmeisteri was comparatively low with no major peaks (Figure 15).

L. hoffmeisteri had decreasing trends on Station 4. On Station 5 numbers were reduced from 1966 through 1970. Sediment composition was similar on upstream sand stations, 3, 4 and 5 (Figures 16 and 17).

Station 10, located 500 ft downstream of the CYAP discharge underwent the most dramatic change of all 17 stations, both in terms of sediment size and biological composition.

During the months before the plant was running, the sediment composition was primarily sand (0.5 to .125 grain size). Except for the spring several centimeters of silt covered the sand substrate. Silting increased during the dredging of the 1-mile discharge canal and intake basin. During early operation of the plant, detrital terraces were found in place of the sand substrate and pockets of silt were present between these terraces.

Coring from the van Veen indicated a comparatively high population of Limnodrilus in these silt pockets while the numbers of this organism remained low in the detrital patches.

Silt levels in the Station 10 area were extremely variable in location during the early operation and 24 months during operation of the plant. Generally the Limnodrilus population decreased from January 1966 through December 1970.

The stations located further downstream (11, 12 and 13) are similar to each other in sediment composition, depth, and vertical temperature gradient. Under certain conditions the heated water passes over these stations well stratified within the top 24 inches of the surface.

Stations in the main river channel (6 and 8) are at a depth of 20 ft and contain bivalves and Scolecolepidis viridis, a polychaete. As yet, no heated water has been observed at depths greater than 10 ft.

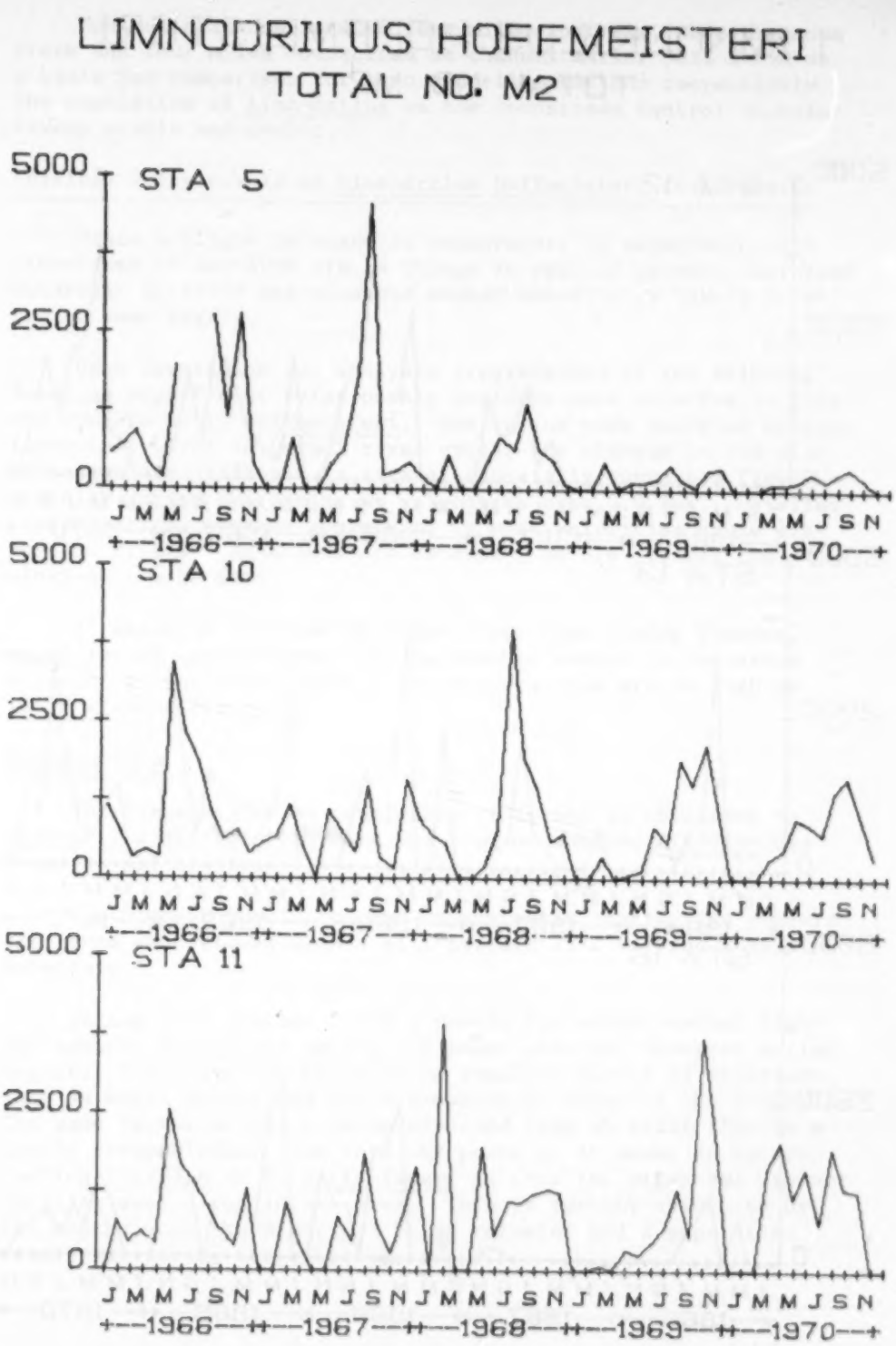

LIMNODRILUS HOFFMEISTERI
TOTAL NO. M2
5000
STA 5
2500
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
5000
STA 10
2500
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
5000
STA 11
2500
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970

Figure 16

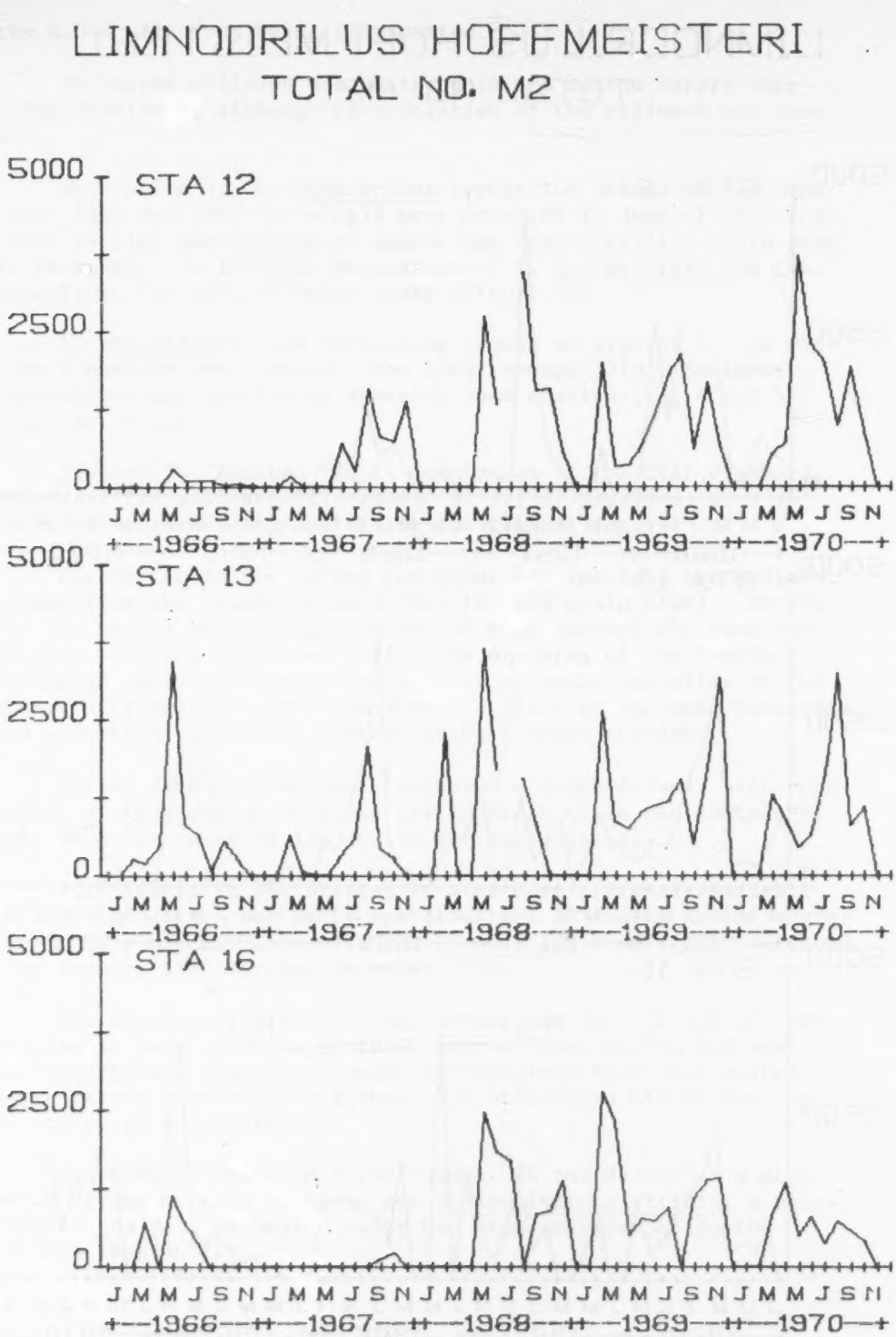

LIMNODRILUS HOFFMEISTERI
TOTAL NO. M2
5000
STA 12
2500
0
J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
5000
STA 13
2500
0
J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
5000
STA 16
2500
0
J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970

Figure 17

Control stations located four miles upstream, near Higganum Creek and four miles downstream at channel marker 38A, serve as a basis for comparison for sand and silt stations respectively. The population of Limnodrilus on the downstream control is relatively stable and cyclic.

Possible Relationship of Limnodrilus hoffmeisteri to Diversion

Since a slight increase in temperature is associated with diversions of 600-4000 cfs, a change in rate of growth, increased metabolic activity and advanced sexual maturity is likely to occur to some degree.

Upon inspection and analysis (regression) of the existing data, no significant relationship could be seen relative to flow and numbers of L. hoffmeisteri. Due to the wide range of monthly flows that exist in normal river cycles the changes in the distribution are difficult to assess, especially where the flows are high during the spring at velocities over 2.0 fps. Detailed investigations seeking answers as to what velocities cause dispersion of these organisms are necessary before further conclusions can be made.

If water is diverted at times other than during freshet, upper lethal temperatures will be reached sooner in the areas adjacent to the power plant where temperatures are as high as 104°F without diversion.

Pisidium spp.

The fingernail clam population is second in abundance to Limnodrilus hoffmeisteri. At one time or another Pisidium was found on all stations.

The highest population and consistently reoccurring numbers are found on stations with a silt surface (1-2 cm) and a sand substrate.

During 1966 Station 2 had a population which reached highest numbers during the spring. A lower peak was observed during August. For 44 months the station remained devoid of organisms. This 44 month period was the pre-operative phase of the study. The same factor of water being diverted from an axial flow to a nearly perpendicular flow into the power plant seems to be affecting Pisidium as L. hoffmeisteri in that the organisms are not settling around the intake area. This is further evidenced by the months when the plant was being refueled and a population reoccurred during the shutdown.

Thus far six species have been identified along the sandy reach upstream of the discharge point (Table 6). The mollusc diversity has declined to a single species Pisidium casertanum.

On Station 3 a decreasing trend is not related to the intake process as are the organisms on Station 2.

Heated water carried by the plume during the different tidal phases is in contact with the sediment for various times. Generally at flood tide the velocities are 1 fps. The heated water is on this station from five to seven hours every 12 hours. The silt component has increased since 1967. This area usually has the coarsest grain size of all of the stations located up and downstream of the discharge point.

Downstream of Station 3 is Station 4 which continues to show the decreasing population of Pisidium. Higher temperatures are found compared to Station 3 (Figure 18). A higher percent of silt had also occurred from 1966 to 1970.

This station had six species of Pisidium during 1966. The dominant species, although low in numbers, is Pisidium casertanum. On stations 5 and 10 the population continued to decline from relatively high numbers before to low numbers after plant operation.

Downstream of Station 5 is Station 10 (500 ft downstream of discharge point). At this location perhaps the most catastrophic changes occurred relative to the 17 sampling locations. The Pisidium population underwent radical changes as the dredging of the canal was concluded. The addition of silt was the first obvious change on the substrate.

Population peaks occurred in March in 1966 at about 60 per M^2 and again in November near 120 per M^2. Silt deposits were observed through all of 1967. Heat was present from October 1967 to refueling in the spring of 1969. A population of 100 M^2 occurred during this time. A relatively low population has been present since the 1968 refueling period.

No population other than an occasional single specimen has been found on stations along the silt downstream stations (11, 12, 13) or in the channel stations (6, 7).

Unfortunately the benthic studies do not offer a solution to the complex change in diversity that has occurred resulting in the survival of two of the six species of Pisidium. Of interest however is the absence of the genus Sphaerium since the dredging

DOMINANT SPECIES COMPOSITION

SPECIES	STATIONS BEFORE 4	5	10	11	16	AFTER 4	5	10	11	16
Annelida										
Oligochaeta										
Limnodrilus hoffmeisteri	+	+	+	+	+	+	+	+	+	+
Polychaeta										
Scolecolepidis viridis	+	+	+	-	+	+	-	-	-	+
Hirudinea										
Placobdella ornata	-	-	-	+	+	-	+	+	+	+
Helobdella stagnalis	-	-	+	+	+	-	-	+	+	+
Erpobdella punctata	-	-	-	-	-	-	-	+	-	-
Isopoda										
Cyathura polita	-	-	-	-	+	-	-	+	+	+
Amphipoda										
Gammarus fasciatus	+	+	+	+	+	+	+	+	+	+
Insecta										
Odonata										
Erythrodiplax sp.	-	-	-	-	-	-	-	+	+	-
Coenagrionidae	-	-	-	-	-	-	+	+	+	-
Macromia sp.	-	-	-	-	-	-	-	+	+	-
Gomphus sp.	-	-	-	-	-	-	-	+	-	-
Trichoptera										
Oecetis sp.	-	+	+	+	-	-	-	-	-	-
Coleoptera										
Hydrophilidae	+	+	+	+	-	-	-	-	-	-
Berosus sp.	-	-	-	-	-	-	-	-	-	-
Elmidae	-	-	-	-	-	-	-	+	+	-
Ephydridae	-	-	-	-	-	-	-	+	+	-
Hydrellia sp.	-	-	-	-	-	-	+	+	+	-
Diptera										
Culicidae	-	-	+	+	+	-	-	-	-	+
Culex sp.	-	-	+	+	+	-	-	-	-	+
Chironomus attenuatus	+	+	+	+	+	+	+	+	+	+
Psectrotanypus sp.	+	+	+	+	+	+	+	+	+	+
Cryptochironomus sp.	+	+	+	+	+	+	+	+	+	+
Glytotendipes lobiferus	-	-	-	-	-	-	+	+	+	-
Ceratopogonidae	-	-	-	-	-	-	-	+	+	-
Gastropoda										
Physa hetherostropha	-	-	+	+	+	-	+	+	+	+
Ferrissia sp.	+	+	+	-	+	-	-	-	-	+
Pelecypoda										
Lampsilis cariosa	+	+	+	-	+	+	-	-	-	+
Elliptio complanata	+	+	+	-	-	+	-	-	-	-
Pisidium adamsi	+	+	+	-	+	-	-	-	-	+
P. aequilaterale	+	+	+	-	-	-	-	-	-	-
P. casertanum	+	+	+	-	+	+	-	-	-	-
P. compressum	+	+	-	-	+	-	-	-	-	-
P. nitdium	+	+	+	-	+	-	-	-	-	-
P. punctiferum	+	+	+	-	-	-	-	-	-	+
Sphaerium corneum	+	+	+	-	-	-	-	-	-	-
S. lacustre	+	-	-	-	-	-	-	-	-	-
S. occidentale	+	-	-	-	-	-	-	-	-	-
S. transvensum	+	-	-	-	-	-	-	-	-	-

(+) = Present
(-) = Absent

Table 6

PISIDIUM SPP.
TOTAL NO. M2

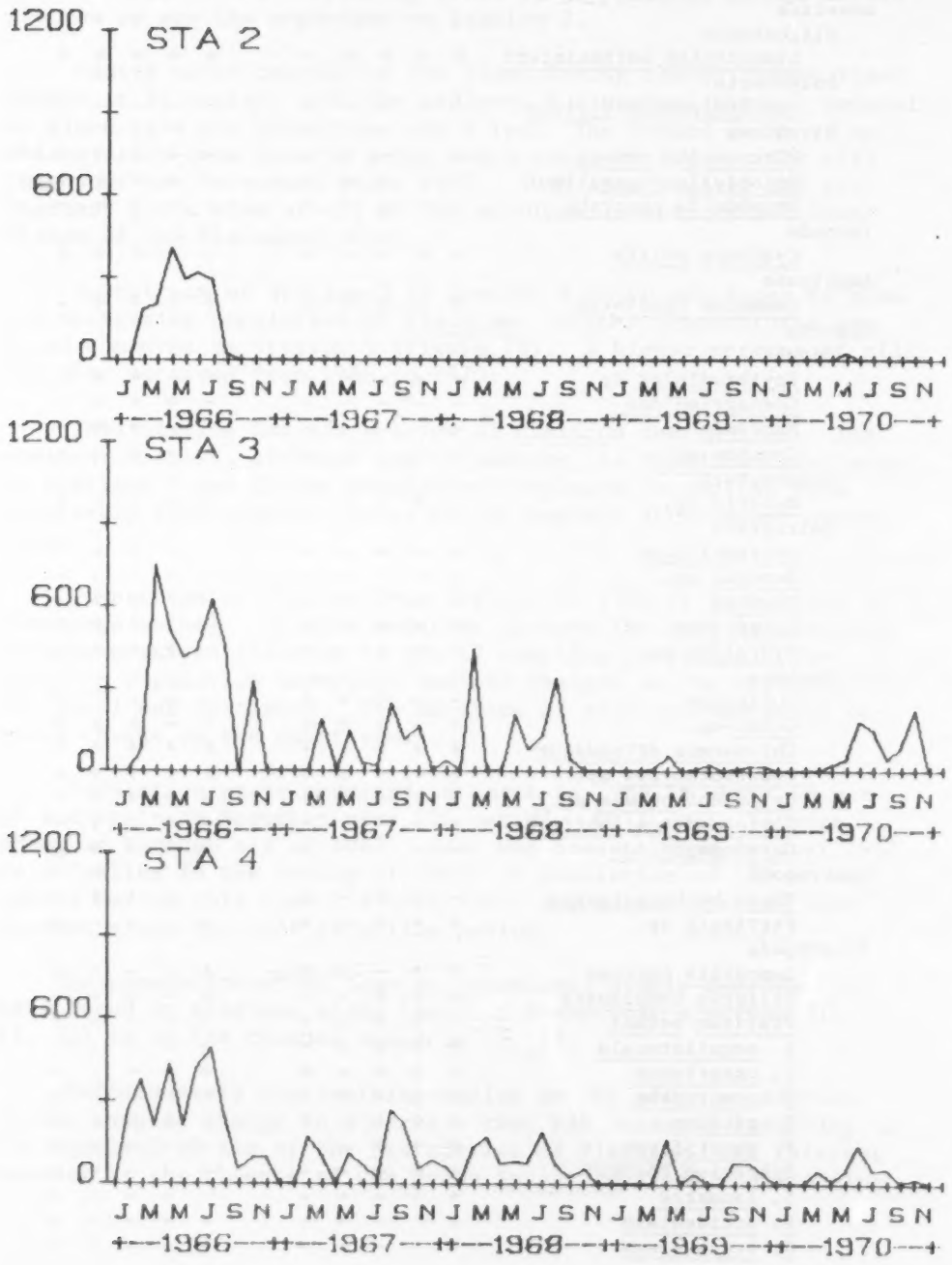

1200
STA 2
600
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
1200
STA 3
600
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
1200
STA 4
600
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970

Figure 18

PISIDIUM SPP.

TOTAL NO. M2

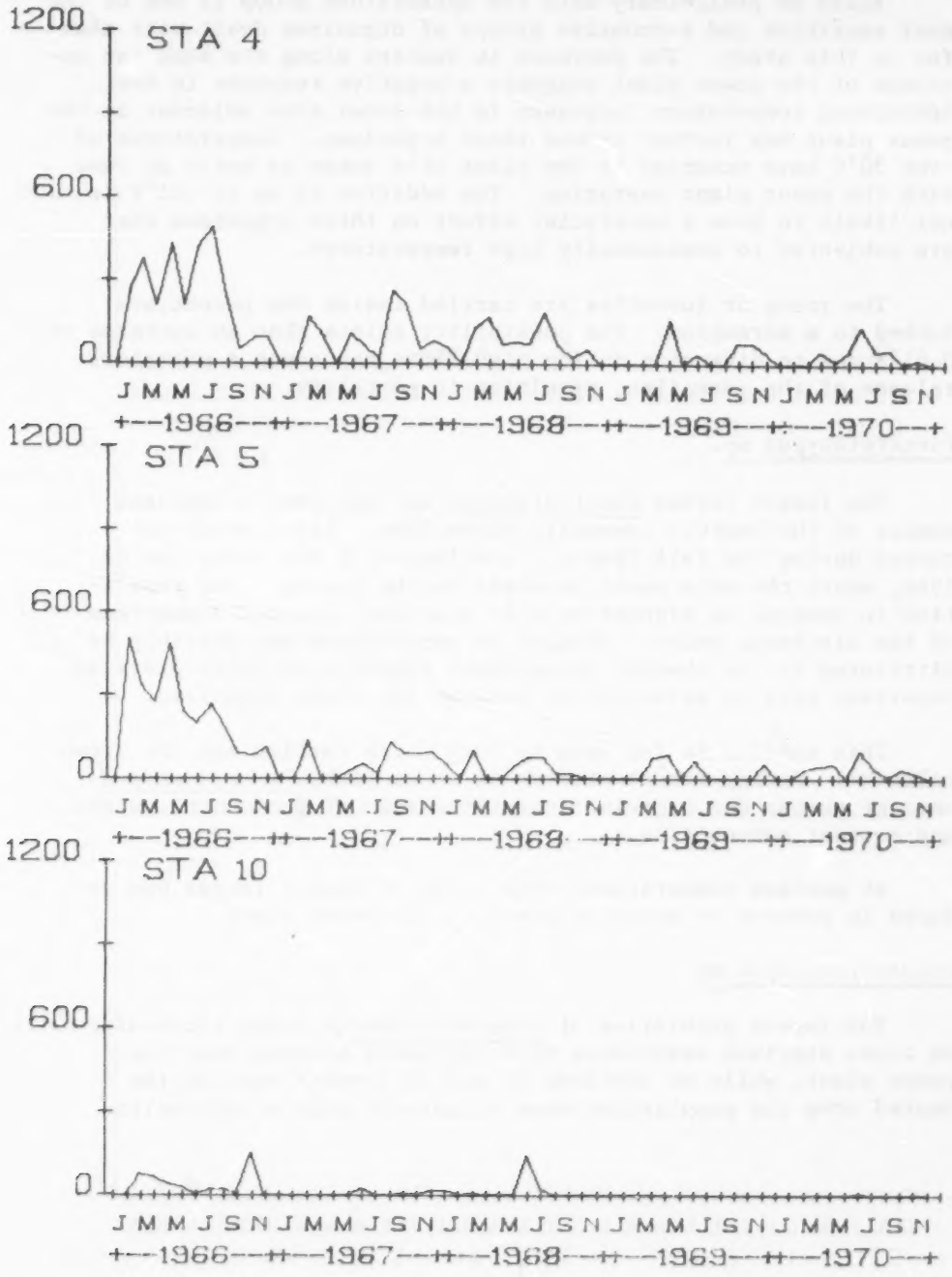


Figure 19

of 1966.

Possible Relationships between Pisidium and Diversion

Based on preliminary data the Sphaeriidae group is one of the most sensitive and responsive groups of organisms dealt with thus far in this study. The decrease in numbers along the sand bar upstream of the power plant suggests a negative response to heat. Additional temperature increases in the local area adjacent to the power plant may further reduce these organisms. Temperatures of over 30°C have occurred in the plant site areas as early as June with the power plant operating. The addition of up to .61°F is not likely to have a beneficial effect on these organisms that are subjected to unseasonally high temperatures.

The young or juveniles are carried inside the parent, attached to a marsupium. The possibility exists that an increase of 0.61°F due to diversion during high flows may cause a premature release of the juveniles, resulting in mortality.

Psectrotanypus sp.

The insect larvae Psectrotanypus sp. has been a dominant member of the benthic community since 1966. Major peaks occurred during the fall from all stations with the exception of 1966, where the main peaks occurred in the spring. The population in general is highest on silt stations, located downstream of the discharge point. Changes in populations may possibly be attributed to the changes in sediment composition which plays an important role in selection of habitat for these organisms.

This species is fed upon by both white catfish and the brown bullhead. During recent studies of these fish, Psectrotanypus was the number one organism insect in terms of dominance, weight, and percent composition.

At maximum temperatures this group of insect larvae was reduced in numbers in areas adjacent to the power plant.

Cryptochironomos sp.

The insect population of Cryptochironomus began increasing on those stations associated with increased heating near the power plant, while on stations 12 and 13 located outside the heated area the populations were relatively stable and cyclic.

PSECTROTANYPUS SP.
TOTAL NO. M2

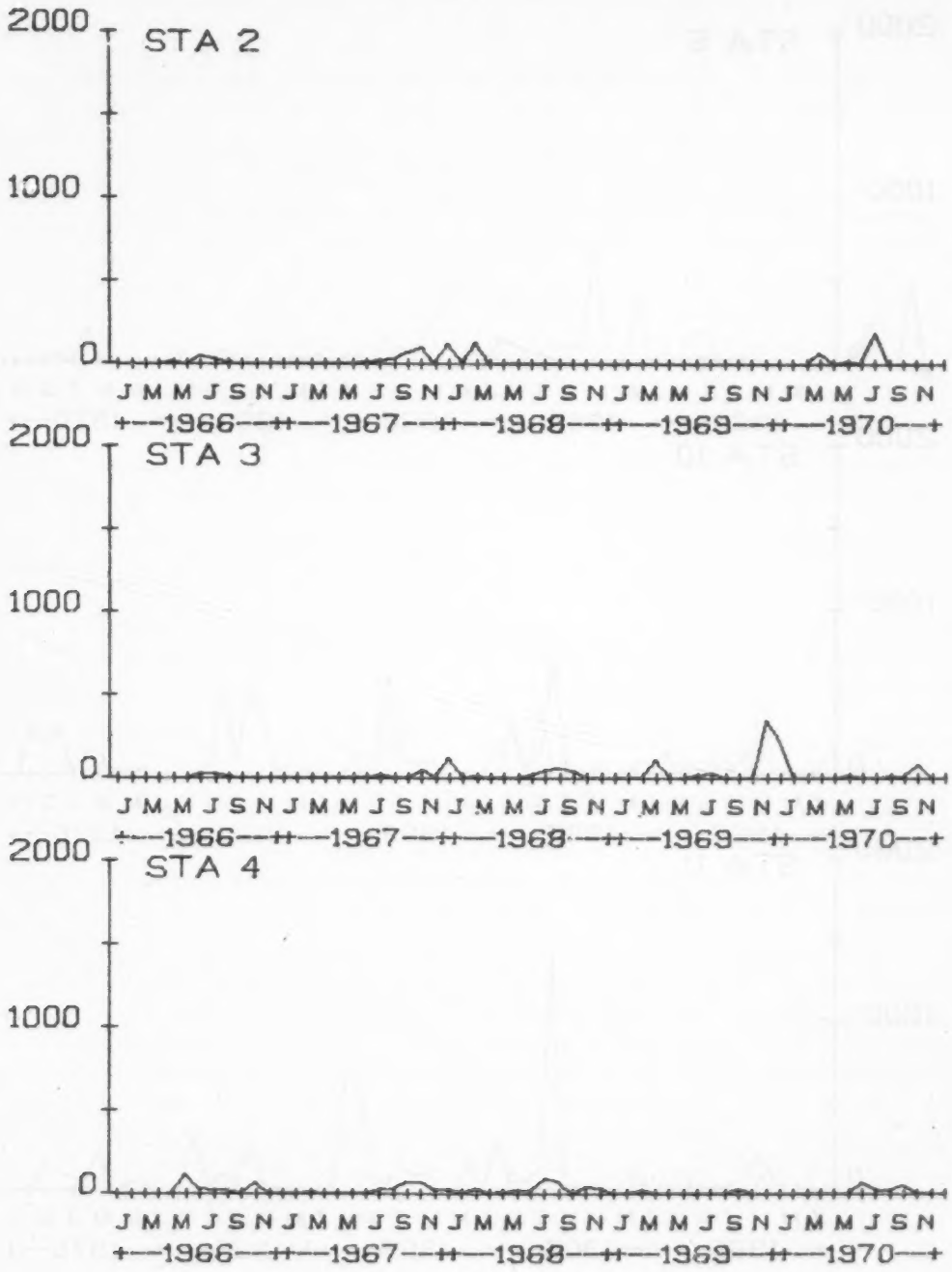

2000
STA 2
1000
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
2000
STA 3
1000
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
2000
STA 4
1000
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970

Figure 20

PSECTROTANYPUS SP.

TOTAL NO. M2

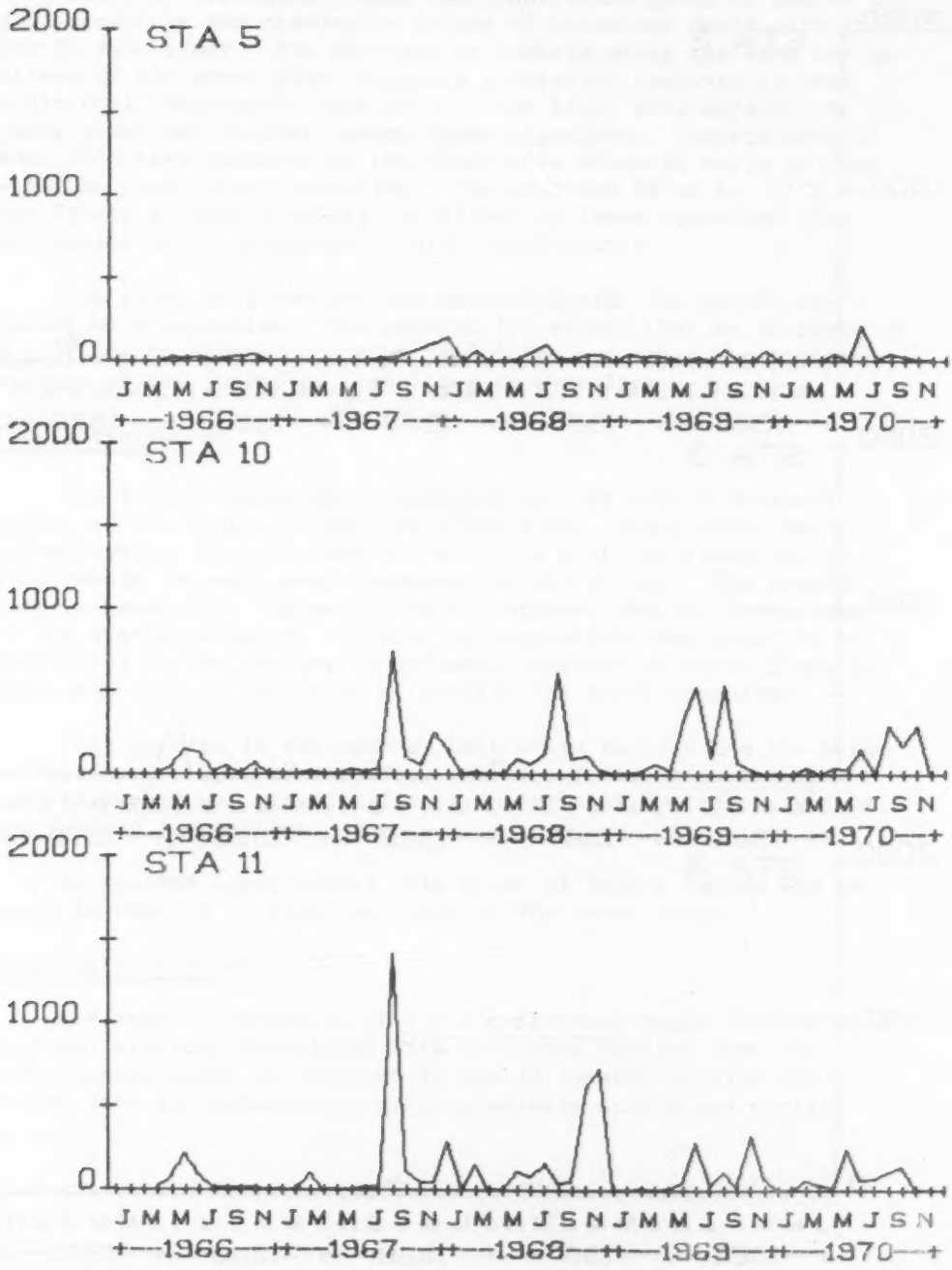


Figure 21

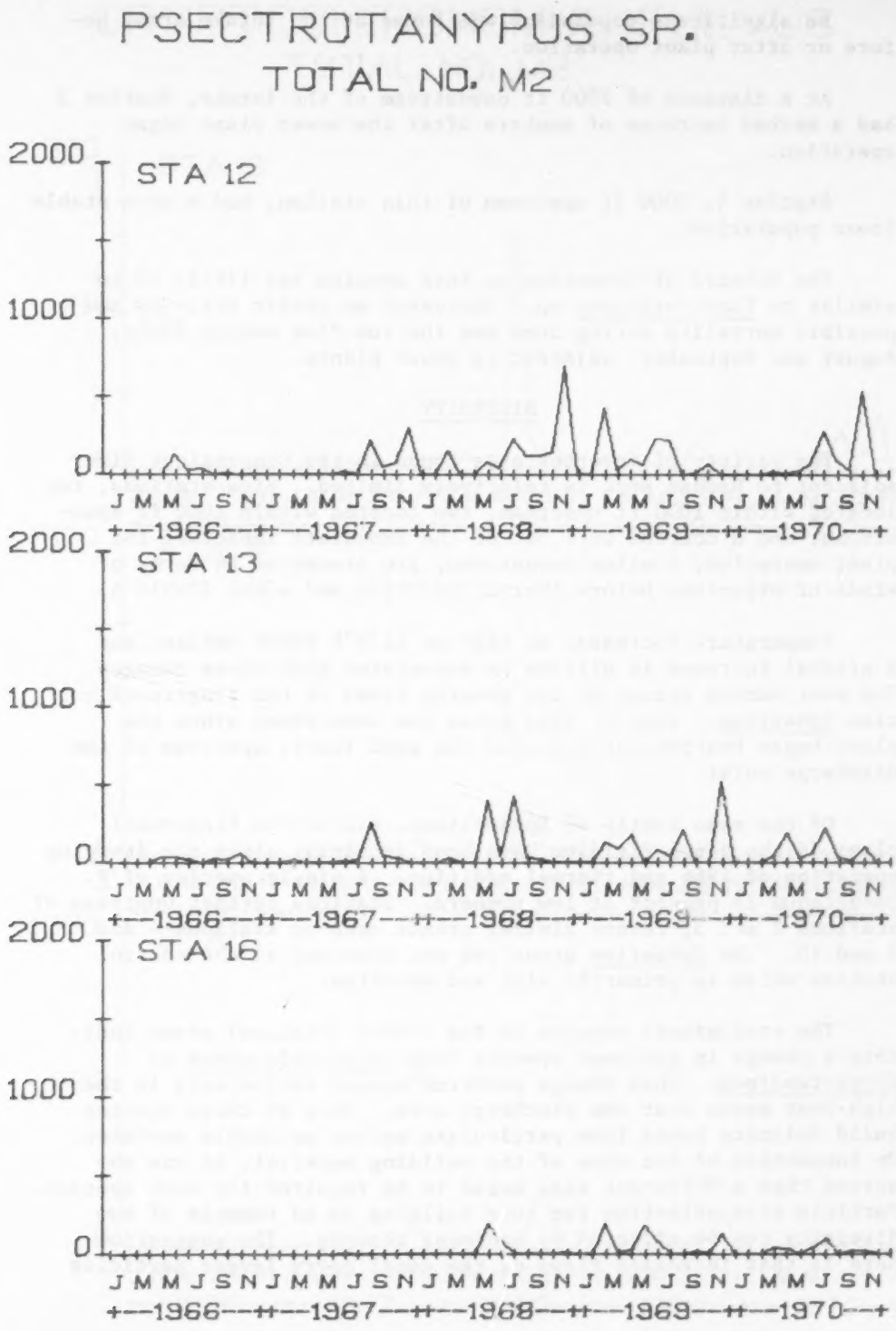

PSECTROTANYPUS SP.
TOTAL NO. M2
2000
STA 12
1000
0
J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
2000
STA 13
1000
0
J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
2000
STA 16
1000
0
J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970

Figure 22

No significant population was found at the intake area, before or after plant operation.

At a distance of 2000 ft downstream of the intake, Station 3 had a marked increase of numbers after the power plant began operation.

Station 4, 1000 ft upstream of this station, had a more stable lower population.

The effects of diversion on this species are likely to be similar to Psectrotanypus sp. Increased metabolic activity and possible mortality during June and the low flow months (July, August and September) adjacent to power plants.

DIVERSITY

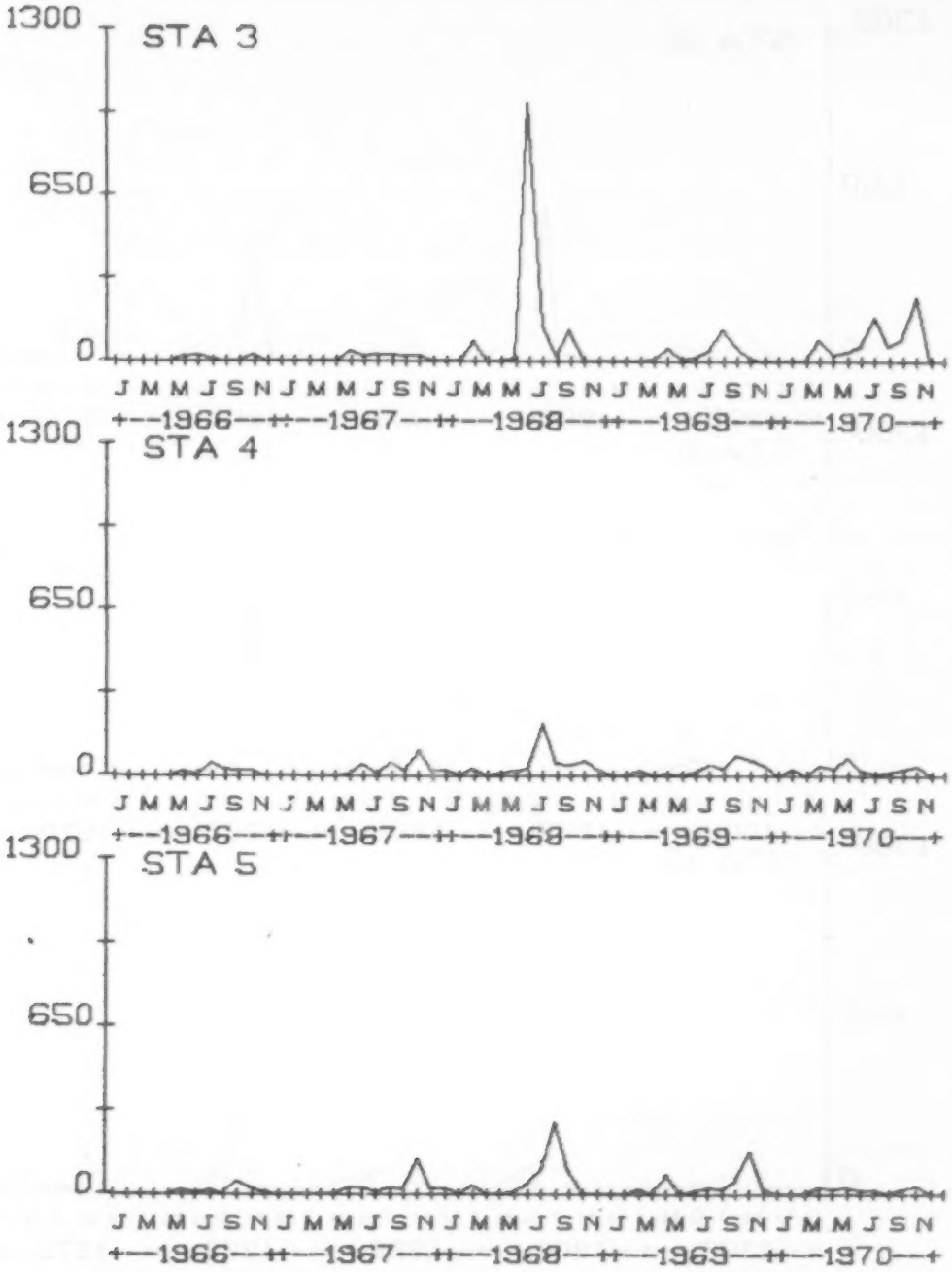
The variety of invertebrates found in the Connecticut River adjacent to Haddam Neck is relatively limited. Five stations, two located within 1000 ft upstream, two located within 1000 ft downstream, and a control well out of the immediate impact of the plant operation, 4 miles downstream, are presented in terms of kinds of organisms before thermal addition and after (Table 6).

Temperature increases as high as 21.4°F above ambient and a gradual increase in silting is associated with these changes. The most marked change at the generic level is the fingernail clam Sphaerium. None of this genus has been found since the plant began heating water around the sand flats, upstream of the discharge point.

Of the same family of Sphaeriidae, all of the fingernail clams of the genus Pisidium have been declining since the dredging operation of 1966 and thermal addition. A single species of P. casertanum is present at low numbers. Stations further upstream of stations 2 and 3, relate similar trends seen on stations 4 and 5 and 10. The Sphaerium group was not observed at the control station which is primarily silt and detritus.

The preliminary results on the insect (diptera) group indicate a change in dominant species from Cryptochironomus to Glyptotendipes. This change occurred almost exclusively in the high heat areas near the discharge area. Both of these species build delicate tubes from particulate matter on stable surfaces. On inspection of the size of the building material, it was observed that a different size seems to be required for each species. Particle size selection for tube building is an example of how diversity can be affected by sediment changes. The suggestion here is that increased flows of the canal carry larger particles

CRYPTOCHIRONOMUS FULVUS
TOTAL NO. M2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650
0
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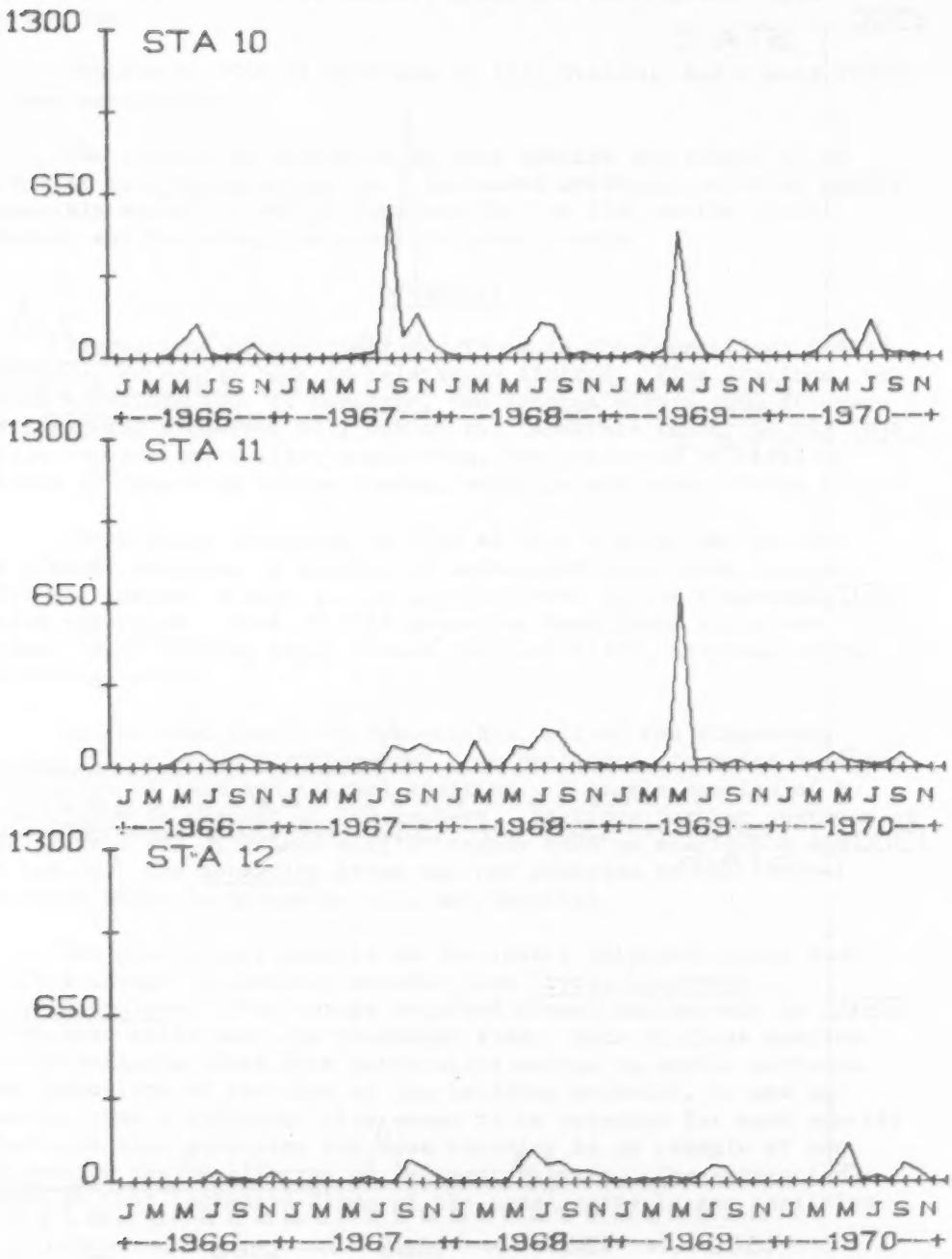
1966
1967
1968
1969
1970
1300
STA 4
650
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
1300
STA 5
650
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970

Figure 23

CRYPTOCHIRONOMUS FULVUS

TOTAL NO. M2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650
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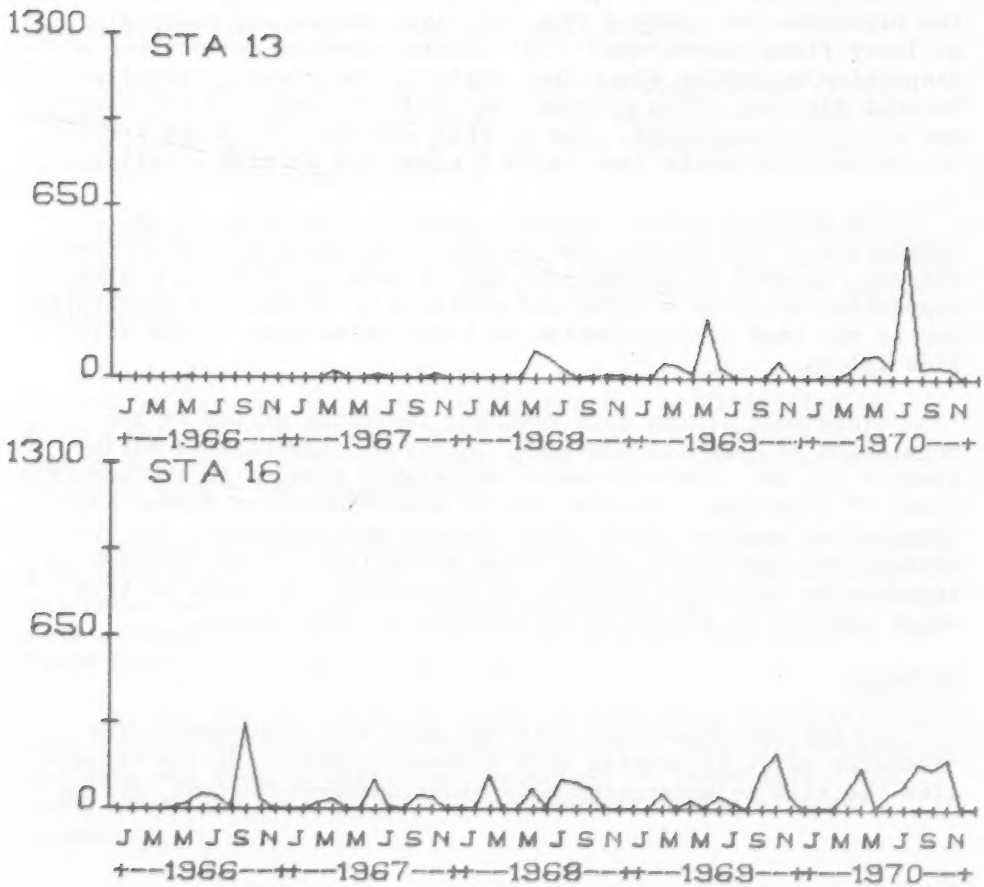
1966
1967
1968
1969
1970
1300
STA 11
650
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970
1300
STA 12
650
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970

Figure 24

CRYPTOCHIRONOMUS FULVUS
TOTAL NO. M2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STA 13
650
0
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1966
1967
1968
1969
1970
1300
STA 16
650
0
J M M J S N J M M J S N J M M J S N J M M J S N J M M J S N
1966
1967
1968
1969
1970

Figure 25

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which are successfully used by Glyptotendipes.

In denoting the nature of the diversity, several aspects can be reviewed that most likely account for low numbers of kinds of organisms.

1. High physiological stress (at temperatures of near mortality (90°F) for insects.

2. Dominance of a single species on the Connecticut, the annelid Limnodrilus hoffmeisteri.

3. A few specific types with a wide range of diets, i.e. periphyta with high abundance of organisms as Psectrotanypus.

4. Large variations in physical qualities of the environment, such as startup and shutdown of power plants, high temperatures, and artificial flow systems.

In general, during times of high flows (freshet) many of the organisms are removed from the river bottom and redeposited at lower flows downstream. This natural phenomenon has been a dispersion mechanism since the origin of the river. Variation between days are often greater than 4000 cfs which is the maximum diversion suggested. The benthic populations during freshet is characteristically low: pisidid clams and aquatic annelids.

The probable effect during freshet is likely to be an alteration of the travel time of the organisms transported downstream. However no predictions can be made as to where a given population would be scoured and replaced on downstream substrates due to the lack of information on local velocities at specific flow values.

Since most of the data reviewed indicates stress on the population at high temperatures, increased temperatures during freshet are not likely to cause detectable changes in the specific kinds of organisms. However should diversion occur during high temperature seasons, June, July, August and September, the increases in temperature could cause mortality. If an increase in temperature occurs as a result of diversion, the range of warm water species is likely to be extended to some degree.

Sediment

During the winter and fall the sand flat upstream of the discharge point is covered with a layer of silt. At low velocities the silt is undergoing only minor changes; however, during

the spring when the velocities are greater than 2 fps the silt is removed from the surface of the sand substrate and carried further downstream. At this time the finer sediment and small organisms are transported until lower velocities occur, in the late spring. Changes occur in the sediment and populations when the water column unloads at these lower velocities. Increases occur especially at the meiofaunal levels (protozoans, nematodes, tardigrades, cladocerans, and copepods).

In attempting to assess the effects of diverting 4000 cfs and less during flows about 12,000 cfs no direct associations with sediment compositions were found. Variations between sampling days which exceed 4000 cfs were examined. No significant values could be observed. Since sediment transport and deposition is generally a function of flow velocity, more data with velocity-sediment values must be obtained before further conclusions can be reached. Based on available information no significant changes in the sediment would occur with a control flow of 12,000 cfs at Montague City.

Temperature Effects on Freshwater Invertebrates

The biological effects of raising the temperature of the aquatic environment are numerous. They range from lethal to subtle changes in behavior, genetic, food chain shifts, metabolic and reproductive activity.

Ushakow (1968) reviewed the literature with respect to (1) adaptation of temperature resistance, protozoans and early stages in multicellular animals; and (2) the resistance of high and low temperatures.

Nebeker and Lemke (1968) tested mature larvae of twelve species of insects to assess their relative sensitivities to heated waters. The 96 hour mean tolerance limit selected as index of thermal sensitivity ranged from 69.8°F for winter stoneflies to 91.4°F for dragonflies.

Temperature requirements for survival and growth of chironomids were studied by Biever (1968). Species with the highest tolerance had the highest temperature optima for rate of development although rearing temperatures optimum for high survival and rapid development did not coincide.

The variability of drift rates of Simuliidae and Ephemeridae were studied by Pearson and Franklin (1968). Multiple regression analysis was used to determine the effect of temperatures and seven other environmental factors to summer drifts of these organisms.

Aston (1968) observed the temperature effects on the growth and life cycle of a tubificid worm inhabiting the warm water effluents in the Thames River. The life cycle was completed in about a year at both ambient and at effluent temperature. Optimum temperatures for cocoon production was 77°F; growth, 50-59°F. In the ambient environment cocoon laying peaked in the summer.

Investigations by Carlisle and Cloudsley-Thompson (1968) on aquatic snails raised to a higher temperature after acclimation showed high oxygen consumption for a short period of time, then returning to normal levels. Consumption was four times greater at 93.2°F for animals acclimated at 68°F and five times higher for animals acclimated at lower temperatures. Decline in consumption was observed after 48 hours after acclimation to higher temperatures.

The effect of increasing water temperatures upon the shift of species of an insect population is represented by Walshe (1948). The index of seven species of midge larvae are suggested to reflect the sequence of their preferred temperatures.

Tanytarus brunnipes	84.2°F
Prodiamesa olivacea	86.0°F
Anatopyna nebulosa	86.9°F
Chironomus riparius	94.1°F
C. albimanus	95.0°F
C. longistylus	95.9°F
Anatopynia varia	101.8°F

Sayle (1928) observed the dragonfly nymph Aeschna showed an initial response of increased activity when introduced into the warmer water. In 48 hours activity decreased back to original levels.

Beeton (1960) described a shift in population structure of the bottom fauna of Lake Erie. This change was possibly a result from an increased temperature in association with chemical changes. The mean annual temperature is approximately 2°F warmer than in 1918 to 1928, when the average temperature was between 1925 and 1930, with no significant change since. The bottom fauna during 1918-1928 was primarily mayfly nymphs, but now are fly larvae (chironomidae) and oligochaete worms.

The temperature effects on reproduction and development on the pond snail Physa gyrina was observed by DeWitt (1955). Oviposition begins when the temperature reaches 50°F. These snails, when kept anaerobically from 32 degrees to 50°F lived three to five times as long as they do when kept at 68°F.

Beliaev (1958) concluded that Daphina magna were not harmed by water temperatures that fluctuated between 39.2° to 53.2°F, in ice covered ponds. Survival was dependent on favorable food supply and water temperatures above 39.2°F.

Hutchinson (1947) published on a freshwater snail Vivparus malleatus which was found to be inactive below 58.5°F. This snail was not active in a range of 62.15 to 81.5°F.

In discussing compound stress effects Wautier and Troiani (1960) report that Gammarus from the Rhone River had a slow rate of respiration at 64.4°F, and the rate increased at higher temperatures.

Sprague (1963) observed on the effects of high temperature exposure of several isopods and amphipods to have a 24 hour lethal temperature of 90°F. Gammarus pseudolimnalus succumbed at 85.3°F.

Physa gyrina was investigated by Agersborg (1932). A population was living in a waste discharge ditch with a water temperature of 82.4° to 95°F, on an annual basis. The snail displayed a maximum rate of production throughout the entire year.

Studying the compound stress of freshwater limpets, Ancylus fluviatilus and Acroloxus laeustris, Berg (1952) published on experiments done at 37.4°F to 42.8°F and at 96.8° to 104°F. Ancylus is normally associated with maximum summer temperatures of 77°F, but at 96.8°F oxygen consumption indicated the limpets were not killed by the temperatures. Death occurred at temperatures above 96.8°F. Acrolexus death occurred at as low as 87.8°F, but oxygen consumption increased up to this temperature level.

The freshwater snail Australorbis glabratus has been studied for schistosomes by Von Brand, Norland and Mann (1948). Oxygen consumption by this snail increased throughout the heat range of 0.3° to 98.6°F. Damage occurred at 105.8°F.

The authors observed that pulmonate snails have a higher rate of oxygen consumption than do the operculate snails, and pulmonate snails with hemoglobin, are apparently independent of oxygen tension.

The effects of temperature on oxygen consumption of trichoptera larvae were studied by Collardeau (1961). He concluded that more oxygen was consumed at higher temperatures but there was no regular relationship. At 32.9 and 50°F oxygen consumption was constant. An increase was observed at 50° and 68°F. Double

consumption occurred at 71.6°F. He concluded that larvae were well adapted below 71.6°F and were under stress above that temperature.

The relationship between body size, oxygen consumption and temperature was studied by Edwards (1958). His conclusions were that oxygen was consumed 2.6 times faster at 68°F than at 50°F.

Luferov (1958) investigated the gas exhange in chironomidae larvae. Measurements were made between 41°F and 95°F for 24 to 26 hours. An increase in gas exchange was noted at 77°F which was three times greater than at 68°F and twenty times greater than at 41°F. The increased respiration at 77°F was thought to be a response to unfavorable conditions. At 95°F most larvae died.

Fraenkel and Herford (1940) researched insect respiration at sublethal and lethal temperatures. He stated death occurred below the temperature of protein denaturation. They also concluded that death occurs independently of oxygen depletion; also death occurred as a result of an accumulation of metabolic waste products which are produced at a rapid rate at high temperatures.

In studying chironomid larvae Konstantinov (1968) observed that as temperature rises the rate of development rises faster than the rate of growth resulting in mature larvae smaller than those reared at lower temperatures. He also stated that larvae selected temperatures lower than their optimal developmental temperatures. He observed that larvae reared at different temperatures required different time intervals to develop, they all needed about the same number of degree hours.

Investigations on the macrobenthic fauna adjacent to a power plant's thermal effluent on the Delaware River by Trembley (1960, 1961) and Coutant (1962) showed a decrease in the population of insects in the heated area during the summer. The immature stages of chironomidae appeared to be tolerant of high temperatures.

Mann (1965) reported that midge larvae are less abundant in heated discharge temperatures of up to 82.4°F.

Temperature was a significant factor in relating to the variability in drift rates according to Pearson and Franklin (1968). We suggested as temperature increases the activity of insects, the probability of being swept by the current increases.

An upper temperature limit for most Chironominae, Pelopiinae, Diamesinae and Hydrobaeninae lies between 86.0°F and 91.4°F. An exception is larvae of the genus Cryptochironomus which have been observed at temperatures from 100.4° to 102.2°F, Curry (1965).

Lagerpetz and Tissi (1968) reported that the duration of ciliary activity in the unionid clam Anadonta cygnea collensis is probably a cellular mechanism depending on the ion permeability of cell membranes and thermostability of ciliary cells. The rate of ciliary activity in this clam is slower to acclimate to temperatures than is the length of ciliary activity.

Polgar and Barangi (1961) discusses Anadonta cygnea collensis and the lower threshold for activity of the central nervous system which was 37.4° to 39.2°F, maximum activity was reached at 75.2°F.

Kondrant'ev (1963) reported that most freshwater clams showed an increase in the amount of water pumped per unit time from 39.2° to 86°F; while at 93.2°F there was a disturbance of the filtering apparatus.

Salinity

Blue crabs, oysters, mussels and estuarine polychates have been taken periodically over the last several years to provide data for radiation analysis. No quantitative or qualitative data were taken relative to the biological composition of the radiation samples.

High populations of mussels and oysters were found approximately 4.5 miles into the river. Barnacles have been collected 8 miles upstream and polychaetes collected 27 miles upstream. Blue crabs were observed at Connecticut Yankee Atomic Power Company, 16 miles upstream.

Since little data are available from the saline portion of the estuary, and since little is known of its biology, it is recommended that a survey be undertaken that will provide information as to the condition of the estuary in terms of species and total numbers. A biological evaluation of this part of the estuary is of critical importance before a judgment can be made as to the effects of diversion.

Temperature Effects on Marine Invertebrates

Other researchers have reported some of the problems associated with increased temperatures, which is a main concern of this report. A brief review follows.

The effects of temperature on species diversity of marine decapods was reviewed by Zarenkov (1967).

The reproduction of this aquatic organisms is generally temperature dependent. The effect of temperature on overwintering and reproduction of a sponge were investigated by Simpson (1968). Tissue reorganization and egg production occurred with rising temperatures above 50°F, but temperatures above 59°F were required for sperm and larvae production.

The effect of increased water temperature on the survival times of sperm cells of marine invertebrates at a variety of salinities were studied by Khlebovich and Lukanin (1967). Also considered were the mussel Mytilus edulis, the polychate Nereis, and the starfish Asterias. High temperatures reduced survival times at low tolerable salinities.

The scallop, Aequipecten irradians, was studied in the laboratory by Sastry (1968). He found the increasing minimum temperature requirements for progressive stages of gamete production that ended at temperatures over 68°F for the production of fertilizable eggs. Low environmental temperatures and low quantities of food restricted breeding to the summer months.

The growth rates of the clam Mercenaria mercenaria throughout its geographic range are related to environmental temperatures. In the northern portion of its range, growth took part in the summer and growth occurred further south almost continuously. An optimum growth of 68°F is indicated, with cessation beyond 46.4°F and 87.8°F. Variation in local populations were related to food availability which determines rates of growth within the limits set by temperature.

Moreira and Vernberg (1968) described the differences in acclimation patterns of a male copepod Euterpina acutifrons. Oxygen consumption at constant and varied temperatures indicated small and larger males were adapted to low and high temperatures in that order.

Studies reported by Barnwell (1968) on coloration of several species of fiddler crab Uca, indicated responses to specific background colors were more vivid at higher temperatures.

The studies of invertebrates passing through the condensers of power plants were undertaken by Markowski (1959-1960). He reported with a rise of 6° or 7°F 35 freshwater species and 62 marine species had survived the passage.

Read (1963) investigated the respiration in two saltwater pelecypods, Mytilus edulis and Brachidontes demissus plicatulus which varied with size of the organism and temperature.

The pumping rates of Mytilus californianus discussed by Rao (1953) indicated that populations separated by 10 degrees latitude had the same pumping rates as populations separated by temperatures of 3.6°F.

RECOMMENDATION FOR FURTHER STUDY

Based on existing benthic data it is evident more information must be obtained. It is recommended that reports from power plants continue to be studied, especially final reports as in the Connecticut Yankee Atomic Power Company study. These reports will provide long term data files with conclusions that may be useful.

MICROBIOLOGY

Any account of the effects of temperature on microorganisms differs in several respects from reports dealing with other groups of living organisms. Firstly, because of the ease and speed with which microorganisms can be cultivated in the laboratory, the effects of temperature on these organisms have been studied more extensively than any other group.

Secondly, the comparative biological simplicity of microorganisms has allowed intensive study. Lastly, the effects of temperature on bacteria has been a very productive area of microbiology, particularly by the food and dairy industries, since heat represents one of the most convenient methods of providing safe, consumable products without seriously altering the taste or appearance of the product itself. However, the temperatures involved are usually those necessary to kill bacterial cells or to inactivate particular enzyme systems. Thus, the extremes of temperature effects are well known. However, the results of slow increase in temperature over a narrow range as a function of time are less well documented. A review by Farrell and Rose (1967) is recommended.

It is known that acclimation of bacteria to higher temperatures is accomplished most readily by gradual increases in temperature by subjecting large populations to extreme conditions for as long as necessary to allow the emergence of stress (temperature)-tolerant organisms. The question then arises as to whether the survivors have undergone physiological adaptation or genetic modification. The latter option seems doubtful since, considering the myriad of biochemical alterations involved in temperature tolerance, several genetic changes would probably be necessary.

Nature is constantly supplying stress in the form of varying temperature and salinity, particularly in estuarine environments and only those organisms capable of adapting comprise resident populations in these locales. These represent marine organisms intruding from seawater and terrestrial and/or freshwater planktonic forms travelling downstream.

One basic difficulty in evaluating the potential effects of temperature and salinity variations on Connecticut River estuarine or freshwater bacteria is defining those organisms which are found there. The microbiology of Long Island Sound (e.g., Murchelano and Brown, 1970) may be quantitatively different from other coastal areas but the overall dominant genera of bacteria is comparable. Because of the relative nearness to land masses

and fresh water drainage, one cannot help but ponder the "marineness" of bacteria isolated routinely from the Sound. While some studies (e.g., MacLeod, 1965) have treated a very few organisms, and have demonstrated a salt requirement, the routine determination of a marine nature of bacteria is not a standard practice.

Temperature presents another situation. It is well known that "marine" bacteria (working definition = those which are isolated from the marine environment and, upon primary culture, require seawater for growth) are generally psychrophilic in nature, having an optimum temperature of $< 68^{\circ}F$, and are extremely sensitive to higher temperatures (Morita, 1966). Any increase in environmental temperature is damaging or lethal. It is doubtful that a truly marine bacterium could penetrate an estuary or river assuming its narrow salinity and temperature tolerance. Similarly, many terrestrial and human bacteria have nutritional or temperature requirements and die off rapidly in relatively nutrient-poor fresh or seawater (Bernard, 1970).

The problem therefore of the ultimate fate of the obligate marine bacteria and some of the fastidious non-marine forms in the environment of slightly, altered temperature or salinity does not seem inordinately significant. What, then, does constitute the "normal" microflora of a body of water such as the Connecticut River? The independent studies of Wolff (1966) and Buck (1970) provide some useful information on bacterial genera most commonly isolated and represent members of the Achromobacterium-Alcaligenes, coryneform, Flavobacterium-Cytophaga-Pseudomonas, Vibrio-Aeromonas and Bacillus groups. All of these organisms are found normally in soils and/or fresh waters. Their appearance in the Connecticut River is a result of run-off from land, part of which is rich agricultural soil. None of these groups as a whole is unusually fastidious with respect to organic requirements or temperature. Some (Pseudomonas sp.) represent the most nutritionally diversified of the bacteria. In short, all are to be expected in natural bodies of water since their environmental adaptibility is known. In a study of Connecticut River microbiology (Buck, 1970) in an area not subject to salinity intrusion colonies consistently developed on media prepared with seawater which were subsequently shown to grow in distilled water and seawater nutrient broth. Conversely, platings made from Fisher's Island Sound (salinity 30 o/oo) show bacteria developing on distilled water media (Pilcher and Buck, unpublished data). Thus, an "all or nothing" effect is not seen in estuarine situations regarding bacteria and salinity tolerance. Apparently, adaptability in these forms is great also.

In studying the effects of thermal effluent on microbiology,

Buck (1970) found that in the immediate mixing area there were indications that some shifts in bacterial genera were occurring. No groups or genera had disappeared in favor of others; only percent distributions varied. It was emphasized that these observations were considered short term ones but that no detrimental significance could be attached to the findings at present. In considering total counts, he found no evidence of pronounced seasonal changes in mesophilic heterotrophic populations nor any effect of thermal effluent. In general, counts were lowest during drought years and increased in an unusually wet year. This was attributed to precipitation and run-off. Psychrophilic forms (those capable of growth at 41°F) showed a dramatic reduction during warm months with maximum numbers recorded during the winter. Counts of thermophiles (growing at 113°F and/or 131°F) showed similar patterns. Laboratory studies revealed that the great majority of both of these groups were, in fact, facultative forms capable of growth at higher and lower temperatures, respectively. Again, the adaptable nature of the "normal" river microflora was seen.

A more detailed study of stream flows and water temperatures (Morrison and Fair, 1966) has shown the relationship of various bacterial counts to these parameters. Some correlations were noted between numbers and water temperatures but they were not major changes. But the concept of major changes can be vague. Both Sieburth (1964) and Oppenheimer and Drost-Hansen (1960) have shown changes in cell morphology or numbers as function of narrow temperature fluctuations. Too little is known of the basic biology of these and other microorganisms to generalize.

Considering the present state of knowledge of bacterial growth and physiology with respect to in situ studies of environmental changes, it is unlikely that drastic alterations would be seen in the "normal" populations of heterotrophic bacteria in the Connecticut River estuary as a function of small changes in temperature or salinity if the changes were gradual and remained constant once changed.

Of potentially greater significance are those microorganisms which do not now appear at a given point in the river but could conceivably become established by a change in one parameter or another. Specifically, fish (Pacha and Ordal, 1962) and shellfish (Andrews, 1954; Ray and Chandler, 1955) pathogens and nuisance organisms such as Spherotilus (Hawkes, 1969) which occur in other areas are known to be influenced by environmental change. There is no evidence to suggest that these or other deleterious forms would appear in the Connecticut River; they are mentioned merely to indicate phenomena. On the other hand, processes such

as sewage decomposition (Brown et al., 1966) and shellfish depuration (Hefferman and Cabelli, 1970) and some fish diseases, (Ordal and Pacha, 1963) are affected beneficially by increased temperature. The blue-green algae are stimulated by temperature rise (Patrick, 1969; Buck, 1970) and have been associated with slimes, odors and reduced grazing stocks for zooplankton and trophically higher macroorganisms. Certain fungus and protozoon parasites may penetrate estuaries and may be distributed by temperature and/or salinity changes.

Based on available knowledge and understanding of the complex aquatic environment, it can be presumed that microbiological changes will occur in the Connecticut River with an alteration in salinity and/or temperature throughout the entire estuarine regime. What is less clear is the extent of these changes and their overall ecological impact. Changes in the "usual" (land derived) bacteria found in the freshwater portions of the river will probably be least affected since their adaptibility to seasonal changes is known. The overall biochemical budget of the river under present conditions and (hopefully) during an upgrading of overall water quality would not suffer from any minor qualitative or quantitative changes in bacterial populations. The portion of the river subject to seawater intrusion presents another situation of somewhat greater unpredictability because of a lack of basic studies on bacteria passing horizontally upward or downward through this region. Of particular importance here are salinity-associated bacteria and other microorganisms which may affect shellfish larvae (Tubiash et al, 1965). No clear-cut prediction can be made for this area but it is unreasonable to presume that no microbial changes will occur. Regretably, too little is known of the variability in physiological types of bacteria found in estuaries in space and time. The numbers and types of phytoplankton present in various reaches of the river warrant perhaps the most careful consideration since these are the primary producers and the important first stage in the complex food chain. Changes in community structure (e.g., diatoms to blue-green algae) could result in greatly modified food stacks in addition to aesthetic deterioration of waters. The relationships of the microalgae to temperature is established in some areas and should be a major consideration in the evaluation of the Connecticut River.

One can be reasonably certain of some overall lack of temperature effects on bacteria in some parts of a river. Present data on the Connecticut River and other areas is sufficient, however, to allow concern about postulated environmental effects on other groups of microorganisms in all parts of the river. While no firm projections on microbiological change can be offered,

there is room for adverse speculation in regard to algal development. The extent of predicted temperature change is small and should not by itself result in immediate, obvious changes in any microbial group. However, combined with salinity change some changes in the microbiota are possible but not unequivocally predictable.

Insufficient information is available on the tolerances of dominant or adventitious microorganisms in the river itself or its estuary to allow a clear forecast of the extent of potential change. Conversely, no change is unlikely. The balance of data on hand suggests that bacterial alterations will be small and will be discernible only in long term studies (several years) and then perhaps not significant to the overall river ecosystem. Studies on specific groups of organisms (microalgae) and the association of certain bacteria and fungi with macroorganisms, particularly in the estuarine reaches, may show more rapid and perhaps adverse effects.

Because of the paucity of the data in some critical areas of basic biology pertinent to the problem considered herein, no absolute prediction can be made regarding the ultimate fate of microorganisms in an estuary subject to changes in salinity and/or temperature. Since, however, the changes are likely to be relatively small (i.e., $< 2°F$ and less than a few parts per thousand salinity) at any given point and will develop over a period of time, no significant qualitative or quantitative alterations in bacterial populations can be presumed to occur within the short run (a few years). Beyond this span no opinion can be offered. Current information on other organisms (algae, protozoa) is suggestive of potentially more rapid alterations in community structure in affected areas over a shorter period of time.

THE POSSIBLE EFFECTS OF DIVERSION ON THE LOWER CONNECTICUT RIVER RESIDENT AND ANADROMOUS FISHES

The purpose of this report is to determine the possible effects of diversion on the resident and anadromous fishes of the lower Connecticut River. Predictions are made only from data obtained from river mile 6.5 to 54, for no information is available regarding the distribution and relative abundance of fish from mile 6.5 to the river mouth.

Although Boyd predicts (Table 3, p. 25) that a .61°F rise in water temperature could result from the maximum postulated diversion at 12,000 cfs, a 2.0°F increment is used in the following sections for more meaningful predictions on the available data.

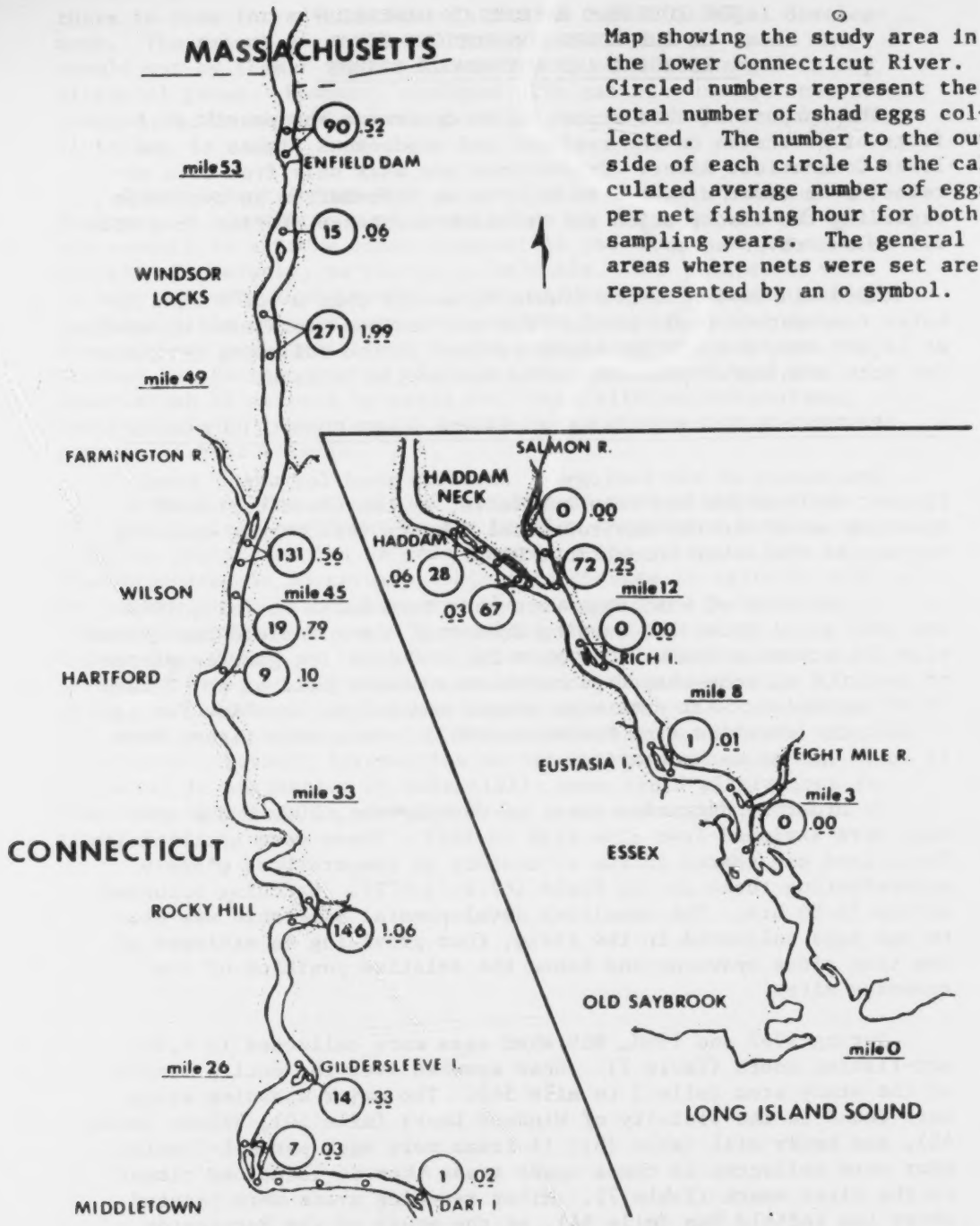
I. SPAWNING OF THE AMERICAN SHAD IN THE LOWER CONNECTICUT RIVER

One aspect of the biology of American shad for which insufficient information has been available, is the distribution of spawning areas and the environmental factors influencing spawning success in the lower Connecticut River.

Collections of shad eggs were made from April to July, 1967 and 1968 at 61 locations ranging from just above Enfield Dam (river-mile 54) to Essex (mile 3) (Figure 26). Collecting gear consisted of ten, 0.5 m, cone-shaped plankton nets constructed of no. 2 mesh (0.39 mm) nylon. All nets were rigged and buoyed to allow for tidal effects (modified from Massmann, 1952). Nets were fished from 12 to 24 hrs at each location.

In order to determine rates of development, 200 to 300 shad eggs were stripped from ripe fish in 1967. These were artificially fertilized and reared in the laboratory at temperatures closely approximating those in the field (67.6-73.4°F). Hatching occurred within 71-86 hrs. The resulting developmental timetable was used to age eggs collected in the field, thus providing an estimate of the time since spawning and hence the relative position of the spawning sites.

During 1967 and 1968, 869 shad eggs were collected in 4,341 net-fishing hours (Table 7). Shad spawned over the entire length of the study area (mile 3 to mile 54). The major spawning sites were found in the vicinity of Windsor Locks (mile 50), Wilson (mile 45), and Rocky Hill (mile 28); 11 times more eggs per net-fishing hour were collected in these upper areas than in locations closer to the river mouth (Table 7). Minor spawning areas were located above the Enfield Dam (mile 54), at the mouth of the Farmington



Map showing the study area in the lower Connecticut River. Circled numbers represent the total number of shad eggs collected. The number to the outside of each circle is the calculated average number of eggs per net fishing hour for both sampling years. The general areas where nets were set are represented by an o symbol.

Figure 26

Summary of collections of American shad eggs from the Connecticut and Salmon rivers, by station, for 1967 and 1968.

Area	River mile	Total net hours		Total number shad eggs		Number eggs collected per hour		Mean eggs per net hour
		1967	1968	1967	1968	1967	1968	1967 and 1968
Enfield Dam area	54	91.50	26.58	88	2	.9680	.0759	.5219
Enfield boat launch	52	120.38	28.58	15	0	.1247	.0000	.0623
Windsor Locks	50	60.55	140.33	216	55	3.5803	.3922	1.9862
Farmington River mouth	46	99.45	135.33	58	73	.5842	.5399	.5620
Wilson	45	24.25	-	19	-	.7867	-	.7867
Hartford	44	24.17	90.50	3	6	.1244	.0664	.0954
Rocky Hill	28	105.53	133.66	21	125	1.1868	.9370	1.06.9
Gildersleeve Island	26	43.25	-	14	-	.3274	-	.3274
Middletown	24	129.53	80.83	6	1	.0463	.0124	.0293
Dart Island	22	50.91	-	1	-	.0197	-	.0197
Haddam Island	18	275.63	153.66	14	12	.0508	.0782	.0645
Haddam neck	16	18.75	1,170.00	0	67	.0000	.0572	.0286
Rich Island	11	93.25	-	0	-	.0000	-	.0000
Eustasia Island	7	126.00	-	1	-	.0079	-	.0079
Essex area	3	111.00	95.00	0	0	.0000	.0000	.0000
Upper Salmon River	-	19.75	394.33	0	0	.0000	.0000	.0000
Lower Salmon River	-	19.66	478.58	7	65	.3608	.1358	.2483
TOTALS		1,413.56	2,927.38	463	406			

Table 7

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River (mile 46), at Gildersleeve Island (mile 26), Haddam Island (mile 18), and in the lower one-mile section of the Salmon River at mile 16 (Figure 26).

Spawning Time

The differences in the time and areas of concentration of spawning were related to river temperatures during May and June of both years. The mean water temperature for May 1967 (51.8°F) was significantly cooler than for May 1968 (59.0°F) ($t = 11.77$, $d.f. = 44$, $p < .005$). The mean egg catch, as calculated from the data in Table 7, occurred at river mile 41.7 during 1967 and further downriver at mile 37.2 during 1968. The observed spawning period ranged from 13 May to 27 June. The peak occurred in June of 1967 and in May of 1968 (Figure 27). Based on daily sport fishery catch records provided by the Connecticut State Board of Fisheries and Game, the median catch day at Enfield Dam (mile 53) for 1967 occurred on 27 May, while in 1968, this occurred earlier on 13 May. Mansueti and Kolb (1953) indicated that ovaries of female shad develop slowly when exposed to temperatures between 55.0 and 65.0°F and develop rapidly between 68.0 and 77.0°F. Cooler temperatures during May of 1967 presumably caused adults to migrate further, as they may not have been ready to spawn until they reached the upper portion of the study area. In 1968, adults arrived earlier when temperatures were warmer and spawned further downstream.

From these observations it may be postulated that a 2°F increase in temperature, as the result of the possible diversion during spring freshet, may cause adults to spawn earlier and further downriver. Daily temperatures were taken at Enfield Dam (mile 53) during the spawning season in 1967 and 1968. A straight line fitted by least squares best described the relationship between recorded temperatures and days. The resulting equations for 55 days in 1967 was $D = -68.06 + 1.6777T$ ($r = .93$) and for 66 days in 1968 was $D = 80.25 + 1.82T$ ($r = .62$). In these equations, D equals day and T equals temperature. Both relationsh ps were found to be linear and highly correlated. Using these equations, the addition of 2°F during 1967 theoretically would have caused spawning temperature to be reached 3.4 days earlier and 3.6 days earlier in 1968. Spawning would also stop earlier at the end of the spawning season. Since less than a 1°F rise is predicted above Middletown, where the majority of spawning was observed to occur, spawning time would change only about a day in both years. The changes in the time of spawning, as the result of the possible diversion, appear to be insignificant.

The ranges in temperature at which shad spawned in the study area were 50.9 - 73.0°F in 1967 and 56.3° - 67.5 F in 1968. Massmann and Pacheco (1957) stated that spawning commences when temperatures

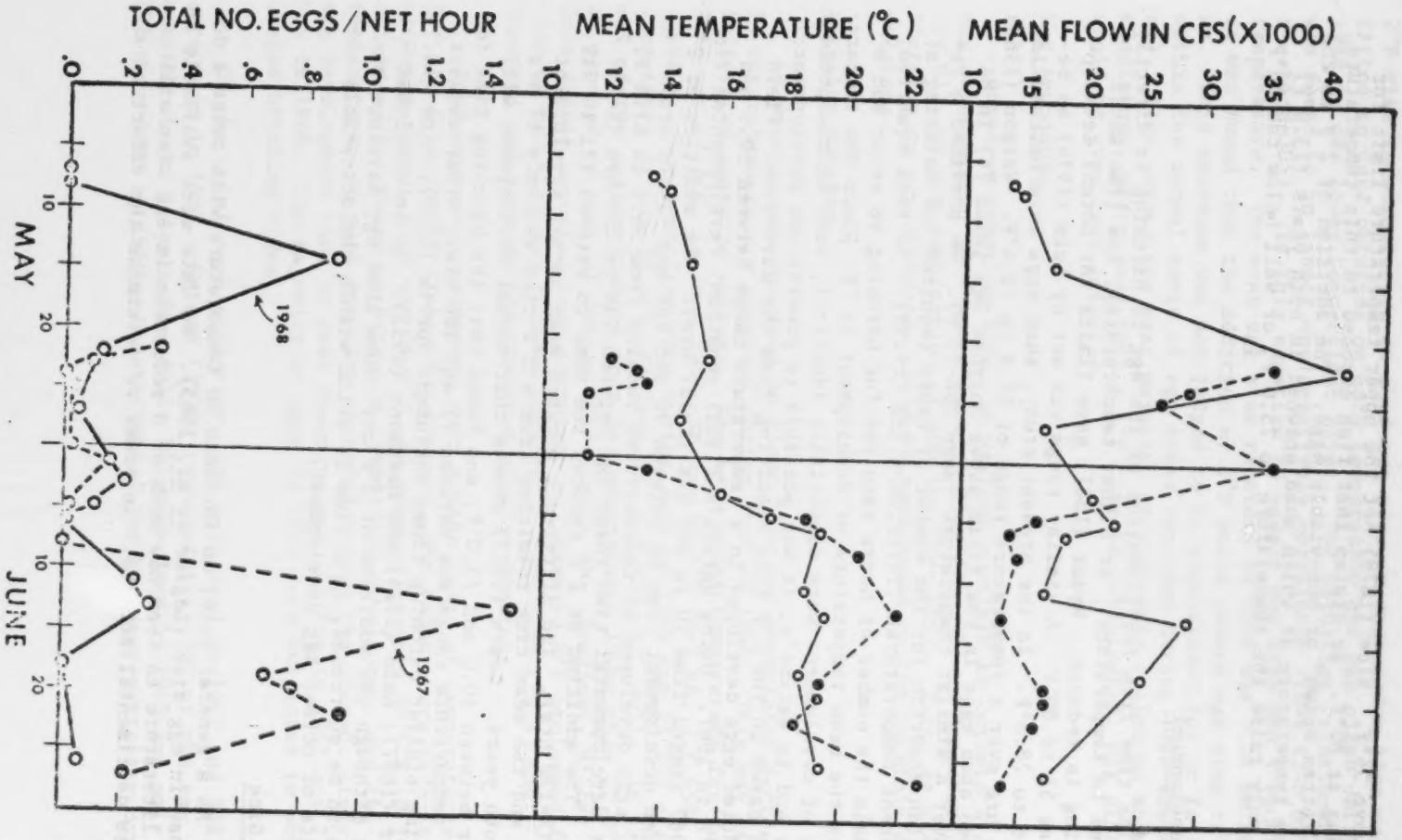

Figure 27

Total number of shad eggs collected per net hour with associated mean river temperatures and flow rates for May and June of 1967 and 1968. Broken lines represent 1967 data and solid represent 1968 data.

are above 54°F. Rice (1878) set the upper temperature limit for spawning at 80°F. He states that fish exposed to this temperature have "rotten spawn" or non-viable eggs. The addition of 2°F to the maximum temperature at which shad spawned in both years (73.0°F) would only raise the temperature to 75.0°F, or well below the 80°F limit.

Egg Development

The time from fertilization of the egg to hatching is directly related to temperature. At higher temperatures, the time until hatching is reduced. Ryder (1887) gave limits for normal development as 55 to 80°F. A similar range was set by Leim (1924) as being 46 to 78.8°F. In the present study, shad eggs were hatched in 71-86 hrs over a temperature range of 67.6 to 73.4°F. Watson (1968) hatched shad eggs in the field above Holyoke Dam (mile 74) in 84 hrs over a similar temperature range (68-73°F). He provided a regression equation for the number of hours required for hatching at different temperatures ($Y=729.06-8.75X$ ($r=.93$)). In this equation, Y equals the number of hours required for hatching to occur and X equals the mean temperature of development in °F. Since the temperatures of development were essentially identical, both in the present study and in Watson's, it was possible to predict new developmental times based on the 2°F rise resulting from the diversion. Field collected eggs developed in a temperature range between 50.9 and 73.0°F in 1967. Using Watson's (1968) equation, developmental time in 1967 ranged from 90 to 284 hrs ($\bar{X}$=187 hrs). The addition of 2°F reduced development time to between 70 and 266 hrs ($\bar{X}$=170 hrs). In 1968, eggs developed in temperatures ranging from 56.3 to 67.5°F. Their developmental time range was between 138 to 236 hrs ($\bar{X}$=187 hrs). The addition of 2°F reduced the time to between 121 to 219 hrs ($\bar{X}$=170 hrs). The difference between mean normal development time and the mean time resulting from a 2°F rise was only 17 hrs in both years. Leach (1925) showed that normal development will occur between 50.0 and 75.0°F, and found that the hatching time for this temperature range was between 72 and 288 hrs. Other workers showing similar hatching times included: Norris (1868), Rice (1878), Ryder (1887), Leim (1924) and Massmann (1952). It is concluded that although the addition of 2°F may cause shad egg development time to be shortened, this time is still within the acceptable limits of normal egg development.

Egg Size

As a general rule, an increase in temperature will cause a decrease in egg size (Lagler et al, 1963). No data were available in the literature to show how much of a reduction in egg size will cause detrimental effects. In order to determine the effect of a

2°F rise in temperature on shad egg size, a regression line was fitted to data obtained on both temperature and egg sizes during 1968 in the lower Connecticut River. The resulting relationship was found to be linear and negatively correlated (ES=4.43-0.02T; r=-.66;N=305). In this equation ES equals egg size and T equals temperature. The mean egg size recorded in 1968 was 3.06 mm and it was found that the addition of 2°F would reduce egg size to 2.84 mm. This decrease was not judged to be significant for it falls within the normal range of egg sizes recorded during 1968 (2.1-3.1 mm). Also, since the vast majority of eggs were collected above Middletown, where less than a 1°F rise is anticipated, egg size would be even less affected.

Egg Abundance

Based on existing data, it was not possible to correlate shad egg abundance in 1967 and 1968 with flow (r=-.05) or temperature (r=.01), or the combination of the two (r=-.005). Thus, no predictions on egg abundance could be made based on the possible diversions.

Spawning Success

A significant increase in river flow and associated decrease in water temperature occurred during June of 1968. This may have influenced spawning success. The mean water temperature for June 1968 was 67.3°F; in June 1967, it was 69.3°F ($t=2.66$, d.f.=58, $p < .025$). The mean flow rate during June of 1968 was 21,290 cfs; in June 1967, it was 15,425 cfs ($t=4.06$, d.f.=58, $p < .005$). In 1968, 65% of the eggs collected were in temperatures lower than 61.0°F, as opposed to only 3% during 1967 (Table 8). Bradford, Miller and Buss (1964) reported that temperatures below 60.0°F prolonged the time of hatching and reduced survival. Both Leim (1924) and Mansueti and Kolb (1953) reported similar findings.

Shad eggs were collected over a wide range of temperatures from 50.0 to 75.2°F (Table 8); however, the temperature at peak spawning during 1967 was 71.6°F, as opposed to only 58.6°F in 1968 (Figure 27). Based on Watson's (1968) egg development and the temperatures of peak spawning recorded during the present study, egg development time at peak spawning was 103 hrs in 1967 and 217 hrs in 1968. The majority of eggs in 1968 were subjected to prolonged hatching times.

Of the total eggs collected, 18% were dead in 1967 and 30% were dead in 1968. Watson (1970) reported that 20% of the egg samples above Holyoke Dam (mile 74) were dead in 1968 and only 13% were dead in 1969. He attributed the high egg mortality during

Table 8

Number of shad eggs taken at various temperatures in the Connecticut River during 1967 and 1968.

Temperature C.	Year	10.0-11.9	12.0-13.9	14.0-15.9	16.0-17.9	18.0-19.9	20.0-21.9	22.0-23.9
Number shad eggs	1967	14	1	-	-	37	207	200
Number shad eggs	1968	-	6	253	48	85	5	3

June of 1968 to widely fluctuating water temperatures and stated that a great number of eggs were probably lost from the study area due to high water conditions.

The low number of juvenile shad collected during the present study in 1968 gave further evidence of poor spawning success in that year (Table 9). Watson (1970) found that juvenile shad were scarce above Holyoke Dam in 1968, when compared to 1966, 1967 and 1969.

Possible Salinity Effects

The vast majority of shad eggs were collected above mile 28, or well above any intrusion of salt water. Leim (1924) stated that the upper salinity tolerance for shad eggs is only 7.5 o/oo. Sixty-three percent of the shad eggs collected in the field during 1967 were 3 hrs old or less, and 91% were 14 hrs old or less (Table 10). Current velocities recorded during the spawning season ranged from .5 to 2 ft/sec. Based on their age when collected, it is estimated that the majority would have traveled a maximum distance of 1 to 4 miles from the actual spawning site. Massmann (1952) and Chittenden (1969) reported that after fertilization shad eggs fall to the bottom and roll along for short distances. Clearly the majority of eggs collected in the present study were close to the actual spawning areas and well above any new salinity influence caused by the possible diversions.

Conclusions

Based on the above existing data, it is concluded that the possible diversions, with a control flow of 12,000 cfs, will not significantly influence shad spawning success. However, any diversions which contribute to rapid fluctuations in river flows and associated water temperatures may negatively influence spawning success in a particular year.

II. POSSIBLE EFFECTS OF DIVERSION ON ICHTHYOPLANKTON (FISH EGGS AND LARVAE)

Upper Temperature Tolerances

The effects of the passage on fish larvae and early juveniles through the condenser cooling-water system of the Connecticut Yankee Atomic Power Company were studied during the peak of larval abundance at the plant's intake from June 30 to July 29, 1970. This study determined the survival rates of fishes and provided information on the upper temperature tolerances of some of the young fishes in the lower Connecticut River. These data are used as a

Mean number of juvenile shad taken twice monthly in bag seine hauls at 12 stations from 1967 through 1970 between river miles 3 and 54 in the lower Connecticut River.

Year	No. of hauls	Mean no. collected per net haul
1967	94	2.94
1968	54	.78
1969	58	8.17
1970	94	11.50

Table 9

Age distribution (hours) of shad eggs collected from the Connecticut and Salmon rivers for 1967.

Egg developmental stage	Estimated age in hours	Number of eggs	Per cent in each stage
Unfertilized	-	6	1.65
Fertilized	0-0-1.0	23	6.35
2 to 32 cell	1.0-2.0	63	17.40
Multicellular	2.0-3.0	136	37.56
Blastula	3.0-5.0	49	13.55
Gastrulization	5.0-14.0	53	14.66
Primitive streak	14.0-25.0	26	7.18
Early embryo	25.0-33.0	1	0.27
Tail separation	33.0-35.0	0	0.00
Middle embryo	35.0-40.0	5	1.38

Table 10

critera to assess the effects of increased temperature due to the possible diversions.

Of the 2,681 larvae and juveniles that were sorted, identified and measured during the experiment, 97.5% were in the post-yolk sac larval stage (2.0-15.0 mm TL), and 2.5% were early juveniles (15.1-40.0 mm TL). Alewives, Alosa pseudoharengus, and blueback herring, Alosa aestivalis, made up 97.6% of the total catch and white perch, Morone americana, 1.3%. The six other species were represented in quantities of less than 1%: Carp, Cyprinus carpio white catfish, Ictalurus catus, American eel, Anguilla rostrata, spottail shiner, Notropis hudsonius, johnny darter, Etheostoma nigrum, and American shad, Alosa sapidissima.

The survival rate of larvae on day 1 (Temperature = 82.4°F), at the end of the plant's discharge canal was 7.5%. At temperatures above 86.0°F, the vast majority of specimens were dead upon reaching the end of the discharge canal. When the temperature in the canal rose above 95°F, 100% mortality occurred during passage through the plant. Most of the surviving fish noted on day 1 were alewives and blueback herring. No living white perch larvae were observed after passage through the plant at 82.4°F. The only survivors taken in the canal at a temperature of 98.6°F were two American eels.

Little information is available in the literature on the upper lethal temperature tolerances of young fishes. Brett (1956) pointed out that the temperature requirements for very young fish are more exacting than adults. The following is a brief summary of the literature with respect to some upper temperature tolerances of the early life stages of those species collected in our study. Edsall (1970) noted a minimum survival of alewife larvae above 82.4°F. He pointed out that reduced survival at this temperature was caused by increased metabolic rate and depletion of larval energy reserves. Pitt et al, (1956) reported that young carp acclimated to 68.0°F, preferred a temperature of 82.4°F, but died at 89.6°F. Ferguson (1958) also confirmed this upper limit and Black (1953) found upper limits at 87.8-93.2°F. Kendall and Schwartz (1968) found the ($LD-_{50}$) for small white catfish acclimated at 68°F, to be 87.8°F. Trembley (1960) collected a few living spottail shiners and American eels in a heated lagoon at 93.2°F, but found the eels died at 104.0°F. Young American shad experience rapid mortality when ambient temperatures are raised from 75.2-82.4°F to 90.5°F (Moss, 1970).

Other investigators have noted mortalities of fishes, or local reduction in the numbers of fish in water temperatures higher than 86°F (Cairns, 1956 and Alabaster and Downing, 1966). The studies

of Kerr (1953) and Markowski (1962) have shown no harmful effects on fish passage; however, both studies involved fish of larger sizes in water temperatures no greater than 82.4°F.

Nineteen fish species (105,838 specimens of eggs and larvae) were represented in the 700 ichthyoplankton net collections at 15 river stations from 1965 to 1969. The eggs and larvae of the alewife and blueback herring (86.6%), white perch (10.6%) and yellow perch (1.6%) made up 98.8% of the total specimens collected in the lower Connecticut River (Table 11).

Based on three years of ichthyoplankton data (1967-1969), and the upper lethal temperature tolerance information suggested in the entrainment studies, it was possible to predict what the mortality of fish larvae might be as the result of a 2°F rise in river temperature due to the possible maximum diversion. Of the six major species collected in the lower river, only alewife, blueback herring and white perch larvae were found in temperature ranges approaching the proposed upper lethal limit of 82.4°F. Alewife and blueback herring larvae were collected at temperatures ranging from 48.9 to 85.3°F. White perch larvae were collected between 56.8 and 82.4°F. Results showed that only in 1968 were the river temperatures sufficiently high enough to be over the lethal limit of 82.4°F upon addition of 2°F. It is important to note that temperatures did not approach the lethal limit until July or after freshet season. The addition of 2°F to the daily recorded river temperatures exceeded the lethal limit during only 6 of the 98 days that larvae were present. Based on the calculated average number of larvae sampled per day in 1968 (21.5 larvae/m^3), it was estimated that 6.1% of the herring larvae population would have been exposed to the lethal temperature limit. It is concluded that the addition of 2°F during freshet would not seriously affect larval survival, although diversion after spring freshet may cause mortalities.

The larvae of the other major species were found in lower temperature ranges: yellow perch, Perca flavescens (45.0 to 60.0°F); rainbow smelt, Osmerus mordax (45.0 to 59.0°F): and carp, Cyprinus carpio (65.0 to 79.0°F). It is known that the carp doesn't reach its upper temperature limit until 89.6°F (Pitt et al, 1956). There is not enough information available in both the present study and in the literature to predict the upper lethal temperature tolerances of the larvae of the yellow perch and the rainbow smelt. Since both spawn at such low temperatures and probably before freshet, it was felt that a 2°F rise would not be detrimental to either species.

Temperatures during Spawning and Egg Development

Table 11

Summary of species collected in 700 plankton tows from 1965 to 1969 at 15 stations in the lower Connecticut River.

Species	Common Name	Number of Eggs	% total catch	Number of Larvae	% total catch
Alosa pseudoharengus	Alewife)				
Alosa aestivalis	Blueback herring)	24,352	93.95	69,304	86.59
Morone americana	White perch	1,056	4.07	8,497	10.61
Perca flavescens	Yellow perch	28	.10	1,270	1.58
Osmerus mordax	Rainbow smelt	221	.85	489	.61
Notropis cornutus	Common shiner)				
Notropis hudsonius	Spottail shiner)	14	.05	31	.03
Cyprinus carpio	Carp	92	.35	262	.32
Lepomis gibbosus	Pumpkinseed)				
Lepomis macrochirus	Bluegill)	-	.00	77	.09
Lepomis auritus	Redbreast sunfish)				
Catastomus commersonii	White sucker	82	.31	52	.06
Ictalurus nebulosis	Brown bullhead	-	.00	2	-
Brevoortia tyrannus	Atlantic menhaden	-	.00	1	-
Fundulus diaphanus	Banded killifish	-	.00	1	-
Erimyzon oblongus	Creek chubsucker	-	.00	1	-
Etheastoma nigrum	Johnny darter	-	.00	1	-
Menidra menidra	Atlantic silverside	-	.00	2	-
Trinectes maculatus	Hogchoker	-	.00	3	-
	Totals	25,845		79,993	

Temperature has a direct influence on spawning success and largely determines egg development time. The purpose of this section is to present temperature data on the six major species as it relates to spawning success and egg development. The combination of data obtained from our field studies and from the literature is intended to serve as a general aid in evaluating effects of temperature increases due to the possible diversions of water.

Alewife, Alosa pseudoharengus:

In the lower Connecticut River, alewives spawn at temperatures ranging between 45.0 and 72°F; the peak occurring between 69 and 71°F. Edsall (1970) reported spawning temperatures were above 60°F in Lake Michigan. The upper temperature limit for spawning was observed in a landlocked population at 73°F (Greeley, 1938) and Cooper (1961) reported upstream spawning migrations of one marine stock ceased at 69-70°F. Oglesby and Allee (1969) found viable alewife eggs at 77°F in a power plant's discharge canal. Edsall (1970) reported that spawning was interrupted above 82°F and that all mature unspawned female alewives captured in the Kalamazoo River at this time contained slightly opaque eggs that could not be fertilized. Edsall (1970) reported egg mortalities of 22% at temperatures between 38.0 and 42.9°F, and 66% between 78.0 and 82.9°F.

Belding (1921) reported that for alewife eggs from marine stocks, the length of hatching period varied inversely with incubation temperature ranging from 13 days at 46.0°F to 2-3 days at 68.0-70.0°F. Edsall (1970) stated that hatching is most successful above 50.0°F and below 80.0°F. He showed that below 51.0°F, 60% of the larvae that hatched were deformed. Edsall (1970) suggested that the lower limit for successful spawning was about 10.0°F below that at which spawning begins. This seems to be an obvious advantage to a fish that spawns in areas subject to wide daily temperature fluctuations. It is possible that the addition of 2°F to natural river temperatures, as the result of diversion, may narrow the temperature range and thus the ability of the alewife to cope with wide daily temperature fluctuations.

Blueback herring, Alosa aestivalis:

In the present study, blueback herring spawned in temperatures ranging from 62.0°F to 80.0°F. Cianci (1969) reports that the temperatures for optimum spawning in the Connecticut River were between 69.8 to 75.2°F. Loesch (1968) observed that blueback herring stopped spawning at 80.6°F in Connecticut waters and Davis et al, (1970) reported that spawning ceased at 75.6°F in Virginia.

Little information is available on relationship between temperature and egg development of the blueback herring. Cianci (1969) successfully hatched blueback herring in the laboratory from eggs taken in a tributary of the Connecticut River in 55 hrs at 74.5°F. Bigelow and Schroeder (1953) reported hatching eggs in 50 hrs at 71.6°F.

White perch, Morone americana:

The white perch was observed to spawn between temperatures of 48.0 and 77.0°F in the lower Connecticut River. The relationship between temperature and developmental time has been reported by several investigators: Ryder(1887) - 6 days at 52.0°F; Foster (1919) - 4 to 4.5 days at 58.0°F; Mansueti (1964) - 2 days at 63.0° F; and Titcomb (1910) - 20 to 24 hrs at 68.0 to 70.0°F.

Yellow perch, Perca flavescens:

In the present study, yellow perch were observed to spawn between temperatures of 45.0 and 51.0°F, the peak occurring at 49.0°F. The literature revealed that spawning takes place from 44.0°F (Breder and Rosen, 1966) to 54.0°F (Titcomb, 1922 and Meehan, 1913). Breder and Rosen (1966) reported that hatching time was 27 days at 47.0°F. Mansueti (1964) reported similar findings between 47.3 and 53.6°F, and stated that the yellow perch has the longest incubation time when compared to other common estuarine fish.

Carp, Cyprinus carpio:

Carp spawned in temperatures ranging between 72.0 and 81.0°F in the lower Connecticut River. Peak spawning was observed to occur at 79.0°F. Sigler (1953) stated that spawning starts between 58.1 and 62.6°F and peaks between 65.3 and 68.0°F.

The relationship between temperature and development time has been reported by several investigators: Struthers (1929)- 4 to 8 days at 62.0 to 65.0°F; English (1952)- 4 days at 71.6°F; Blaylack and Griffith (1971) - 60 hrs at 78.8°F; and Swee and McCrimmon (1966) - 50 hrs at 89.6°F.

Rainbow smelt, Osmerus mordax:

Rainbow smelt were observed to spawn between 42.0 and 51.0°F (peak at 44.0°F) in the lower Connecticut River. Bigelow and Schroeder (1953) reported spawning at 40.0 to 42.0°F.

Incubation times have been reported by Hale (1960) and

McKenzie (1964) as 19 to 20 days at temperatures ranging between 41.0 and 46.4°F. Hoover (1936) showed a development time of 10 days at 59.0°F.

McKenzie (1964) reported that a sudden decrease in flow during the spawning season left many smelt eggs exposed and caused a high egg mortality. Huntsman and Sparks (1924) stated that the upper lethal temperature tolerance of smelt eggs lies between 70.7 and 83.3°F.

Temperature and Larval Growth

Increasing temperatures influence the rate of larval growth and extremes may induce mortality (U.S.Senate, 1968). Martin (1939) pointed out that a change in temperature during development of fishes may have a great effect on body form. He shifted 20 mm rainbow trout from 46.0 to 60.0°F and found that the growth rate increased. He also found that the fish had larger heads and fins as the result of the shift. Jean (1945) found that Atlantic herring larvae showed slower growth rates, had smaller heads and more vertebrae in colder waters than those from warmer waters.

In the present study, the relationship between temperature and larval growth was examined for the alewife, blueback herring and the white perch. A straight line fitted by least squares best described the relationship for each species. The resulting equation for 278 alewife and blueback herring larvae was LS = 1.83 + .218 T (r= .48), where LS equals larval size in mm, and T equals temperature (F). The relationship was found to be linear and highly correlated. The addition of 2°F to the growth equation only increased the larval growth by .24 mm. The growth regression equation calculated for 137 white perch larvae was LS = 1.95 + .086 T (r= .33). The addition of 2°F only increased larval growth by .1 mm. It is concluded that the addition of 2°F would not significantly alter the growth pattern of the three major species.

Temperature and Larval Yolk-sac Size

An increase in temperature has an accelerating effect on metabolic rate. Marr (1966) pointed out that high temperatures cause the rapid depletion of yolk-sac reserves due to an increase in metabolic rate. Edsall (1970) found a decrease in survival time of unfed alewife larvae with increased temperature above 58-59°F. He stated that this decrease probably reflects the accelerating effect of high temperature on metabolic rate and depletion of larval energy reserves. Cianci (1969) showed that yolk-sac absorbtion occurs in alewives in 72 hrs at 53.0°F in the Connecticut River. He also showed that blueback herring larvae absorbed their yolk-sacs in 72 hrs at 74.5°F.

In the present study, yolk-sacs were found among both alewives and blueback herring larvae between 57.5 and 78.9°F. The mean yolk-sac size (.41 mm) occurred at 66.4°F. White perch larvae had yolk-sacs between 57.5 and 78.2°F and the mean yolk-sac size (.89 mm) occurred at 68.9°F. Regression equations were calculated for the three species to test the relationship between yolk-sac size and temperature. No significant correlations were found and hence it was not possible to predict the effect of a 2°F rise on yolk-sac absorbtion based on existing data.

Temperature and Egg Size

In general, an increase in temperature will cause a decrease in egg size (Ricker, 1970). Very little research has been done on the effects of higher temperatures on egg size. Martin (1939) provided experimental evidence that hatching sizes of fish are larger at higher temperatures.

Two species which spawn during spring freshet and are thus susceptible to a 2°F rise in temperature are the northern pike, Esox lucius and the alewife. Hassler (1970) found that northern pike embryos are tolerant of diurnal temperature changes of up to 7.1°F. Edsall (1970) stated that alewife eggs develop normally between daily temperature fluctuations of ±1.2 to 3.2°F. It was felt that a 2°F rise in temperature due to diversion would not affect survival of these species.

III. POSSIBLE SALINITY EFFECTS

Salinity Tolerance Levels

The following is intended as a literature review of the salinity tolerances of the young of 13 species found in the lower Connecticut River. Lagler et al, (1963) summarized the effects of high salinity on freshwater fish eggs - "If salt content of water is intolerably high, the eggs of freshwater fishes immersed therein would lose water and die by shriveling." If the salinity gradient was allowed to penetrate further up the estuary due to future diversions, the following river species salinity tolerance levels should be closely scrutinized: American shad - 7.5 o/oo (Leim, 1924); red fin pickerel - 8.7 o/oo (Schwartz, 1960); chain pickerel - 22 o/oo (Shoemaker, 1945); carp-spawning limit 10 o/oo (Berg, 1949) - 1.5 to 3.0 o/oo is lethal in 1.5 days (Black, 1951); Golden shiner - 14.4 o/oo (Hildebrand and Schroeder, 1928) - spottail shiner - 10.7 o/oo (Mansueti and Scheltema, 1953); white sucker - 2.0 o/oo (Mansueti and Hardy, 1967); white catfish - 14.5 o/oo (Schwartz, 1964); brown bullhead - 7.6 o/oo (Schwartz, 1964) - observed dying at 14.0 o/oo (Springer and Woodburn, 1960); white perch - larvae withstand 8 o/oo (Mansueti, 1964); alewives and bluebacks spawn in less than 1 o/oo (Davis et al, 1970); smelt -

floating eggs in seawater kills eggs (Bigelow and Schroeder, 1953).

Possible Introduction of New Species into Estuary

The southernmost station in the resident fish survey for the Connecticut Yankee Atomic Power Company study is located at Brockway Island, approximately 6.5 miles north of the mouth of the Connecticut River. Ten marine species have been collected at this station since 1965 which have not been collected further north.

Meade (1966) showed that the salinity gradient doesn't penetrate beyond Brockway Island during spring freshet and wouldn't until late July or early August. If the salinity gradient was allowed to penetrate further north due to further water diversions, the following species may also penetrate further up the estuary: bay anchovy, Anchoa mitchilli; striped killifish, Fundulus majalis; Crevalle jack, Caranx hippos; northern pipefish, Syngnathus fuscus; weakfish, Cynoscion regalis; Atlantic herring, Clupea harengus; Atlantic silverside, Menidia menidia; bluefish, Pomatomus saltatrix; Atlantic tomcod, Microgadus tomcod; and the fourspine stickleback, Apeltes quadracus.

No biological data is available regarding the distribution and relative abundance of fish from mile 6.5 to the Connecticut River mouth. As apparent from the station mentioned above, this area is a vast nursery ground for many marine species. It is impossible to judge the effects of the further intrusion of salt water into the estuary due to diversion without at least some limited studies of the life stages of fishes in this lower part of the estuary.

IV. RESIDENT FISHES (ADULTS)

Food Studies

During 1969 and 1970, an investigation of the feeding habits of the white catfish and brown bullhead was initiated in the area of the CYAP discharge canal. Results from early spring 24 hr studies showed that both species appear to begin feeding at 40.0°F. Tagging of 8,000 specimens of both species indicated that each generally winters over out of the main river system or back in the various coves. Creel census data and early spring tag returns around the Haddam area suggest that both species move out of the coves into the main river at about 40.0°F.

A regression analysis was run to predict the number of days that 40.0°F would occur earlier in 1969 and 1970 as the result of adding 2°F to the data. The daily temperatures for March of both

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years were run against time in days. The resulting equations for March 1969 (N = 31) was D = 1.27 + 4.81 T (r= .58) and D = -4.65 + 6.14 T (r= .77) for March 1970. Both regressions were significant and highly correlated at P = .01. The test results suggest that the addition of 2°F due to diversion would have caused 40.0°F to be reached 4.3 days earlier in 1969 and 6.8 days earlier in 1970. Fish which are wintered over in the coves probably wouldn't detect this increase in the main river during spring freshet. However, the possibility exists that the food supply may be between 4 and 7 days ahead of normal when 40.0°F is reached in the coves. More information is needed to draw any further conclusions from these test results.

Relative Abundance and Occurrence of River Fishes

Table 12 shows a summary of 38 fish species by number and weight collected in bag seines and trawls in the lower Connecticut River from 1965 to 1970. Six other species (bottom of Table 12) have been collected by different fishing methods. Table 13 shows the fish species listed by rank in both numbers and weight. These data provide a source of reference for the relative abundances of fishes in the lower Connecticut River and may be useful in assessing any future impacts due to diversion.

Figures 28 through 38 provide data on the relationships of temperature to the relative abundance and seasonal occurrence of both juveniles (0-year) and adults of the six major resident and anadromous fish species (excluding American shad). In the figures, Alosa spp. refers to the alewife and blueback herring only. These data were obtained before and after the operation of the CYAP facility. Station 9 (top graph) is located at river mile 16 and is the northern control station in the CYAP study area. Station 6 (middle graph) is located at the mouth of the CYAP discharge canal and is subjected at times to a 22.8°F rise in temperature. Station 2, located at Brockway Island (mile 5), is the southern control station.

There has been local minor shifts in the distributions of some species as the result of the higher temperatures produced by the CYAP facility. The majority of fish are prevalent in the river after spring freshet, especially the more temperature sensitive juveniles. It is concluded that the possible diversions made only during spring freshet will not alter the temperature regime enough to affect the fish populations in the lower Connecticut River .

Altering the natural temperature regime through diversion after freshet season may have serious consequences. For example,

Summary of resident and anadromous fish species by number, collected by bag seine and trawl in the Lower Connecticut River from 1965 to 1970. Total weights represent 1965 to 1967 data only.

Species	Number Collected		Total	Total Weight (Grams)
	Adult	0-Year		
B. tyrannus	214	10,907	11,121	1,855
A. sapidissima	40	1,131	1,171	1,500
A. pseudoharengus	322	5,207	5,529	29,808
A. aestivalis	394	2,986	3,380	14,187
Alosa spp.	3,895	63,961	67,856	71,958
C. harengus	0	1	1	0
O. mordax	129	132	261	1,450
A. mitchilli	16	316	332	100
E. americanus	42	16	58	1,685
E. lucius	32	14	46	4,807
C. commersonii	117	109	226	41,672
E. niger	4	0	4	2,110
C. carpio	160	5	165	144,855
N. crysoleucas	1,100	626	1,726	16,836
N. hudsonius	7,074	13,052	20,126	58,407
N. cornutus	59	7	66	125
M. tomcod	8	13	21	240
A. rostrata	728	6	734	65,975
I. catus	3,682	3,694	7,376	105,647
I. nebulosus	6,261	2,499	8,760	210,319
I. punctatus	3	5	8	0
F. heteroclitus	820	370	1,190	3,444
F. majalis	2	5	7	45
F. diaphanus	495	1,537	2,032	3,572
S. fuscus	4	0	4	10
M. menidia	78	560	638	1,157
A. quadracus	0	1	1	5
G. aculeatus	1	0	1	5
P. flavescens	715	140	855	41,730
E. nigrum	679	250	929	2,884
P. saltatrix	1	13	14	145
C. hippos	1	4	5	15
L. gibbosus	370	531	901	9,341
L. macrochirus	13	24	37	760
Lepomis spp.	48	394	442	3,847
A. rupestris	2	0	2	0
L. auritus	19	0	19	1,065
M. salmoides	7	5	12	1,415
P. nigromaculatus	14	0	14	720
M. americana	3,132	21,992	25,124	307,721
M. saxatalis	0	0	0	0
T. maculatus	0	0	0	0
S. atromaculatus	0	0	0	0
S. corporalis	0	0	0	0
C. regalis	0	0	0	0
M. dolomieui	0	0	0	0
Totals	30,681	130,513	161,194	1,151,417

Table 12

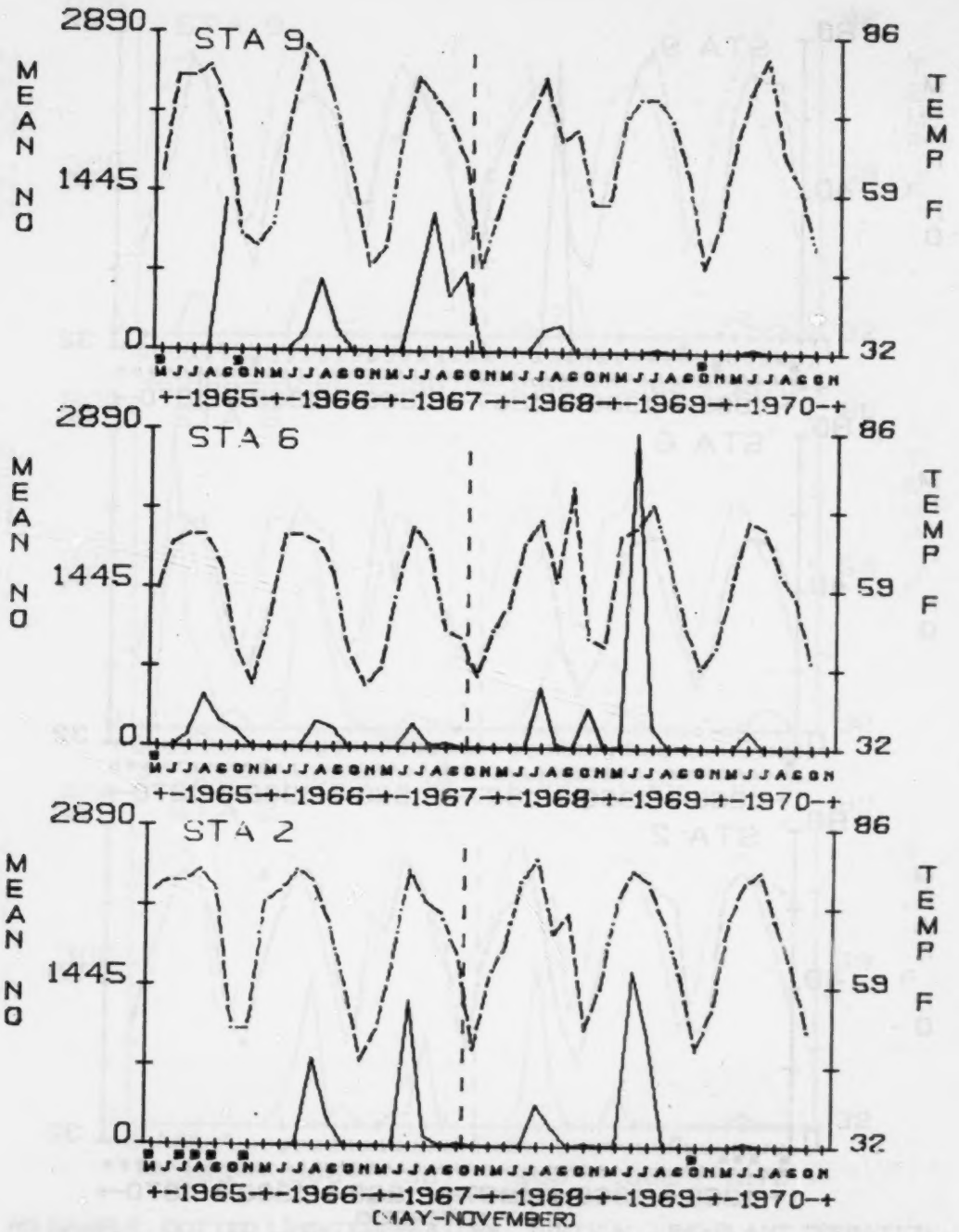
Rank of fish species by number and weight collected in the lower Connecticut River from 1965 to 1970.

Scientific Name	Common Name	Rank in total Numbers	Rank in total Weight
Alosa aestivalis)	Blueback herring		
Alosa pseudoharengus)	Alewife	1	4
Morone americana	White perch	2	1
Notropis hudsonius	Spottail shiner	3	7
Brevoortia tyrannus	Atlantic menhaden	4	17
Ictalurus nebulosus	Brown bullhead	5	2
Ictalurus catus	White catfish	6	5
Fundulus diaphanus	Banded killifish	7	13
Notemigonus crysoleucas	Golden shiner	8	10
Lepomis gibbosus)	Pumpkinseed		
Lepomis macrochirus)	Bluegill	9	11
Lepomis auritus)	Redbreast sunfish		
Fundulus heteroclitus	Mummichog	10	14
*Alosa sapidissima	American shad	11	19
Etheostoma nigrum	Johnny darter	12	15
Perca flavescens	Yellow perch	13	8
Anguilla rostrata	American eel	14	6
Menidia menidia	Atlantic silverside	15	22
Anchoa mitchilli	Bay anchovy	16	28
Osmerus mordax	Rainbow smelt	17	21
Catostomus commersonii	White sucker	18	9
Cyprinus carpio	Carp	19	3
Notropis cornutus	Common shiner	20	27
Esox americanus	Redfin pickerel	21	18
Esox lucius	Northern pike	22	12
Microgadus tomcod	Atlantic tomcod	23	25
Pomoxis nigromaculatus	Black crappie	24	24
Pomatomus saltatrix	Bluefish	25	26
Micropterus salmoides	Largemouth bass	26	20
Ictalurus punctatus	Channel catfish	27	32
Fundulus majalis	Striped killifish	28	29
Caranx hippos	Crevalle jack	29	30
Morone saxatilis	Striped bass	30	23
Esox niger	Chain pickerel	31	16
Synathus fuscus	Northern pipefish	32	31
Gasterosteus aculeatus	Threespine stickleback	33	33
Apeltes quadracus	Fourspine stickleback	34	34
Clupea harengus	Atlantic herring	35	35
Ambloplites rupestris	Rock bass	36	36
Cynoscion regalis	Weakfish	37	37

*Juveniles only

Table 13

RESIDENT FISH SURVEY-ALOSA SPP.
0-YEAR



* NO SAMPLE DOTTED LINE-TEMPERATURE VERTICAL LINE-PLANT OPERATION

Figure 28

PESIDENT FISH SURVEY-ALOSA SPP.

ADULT

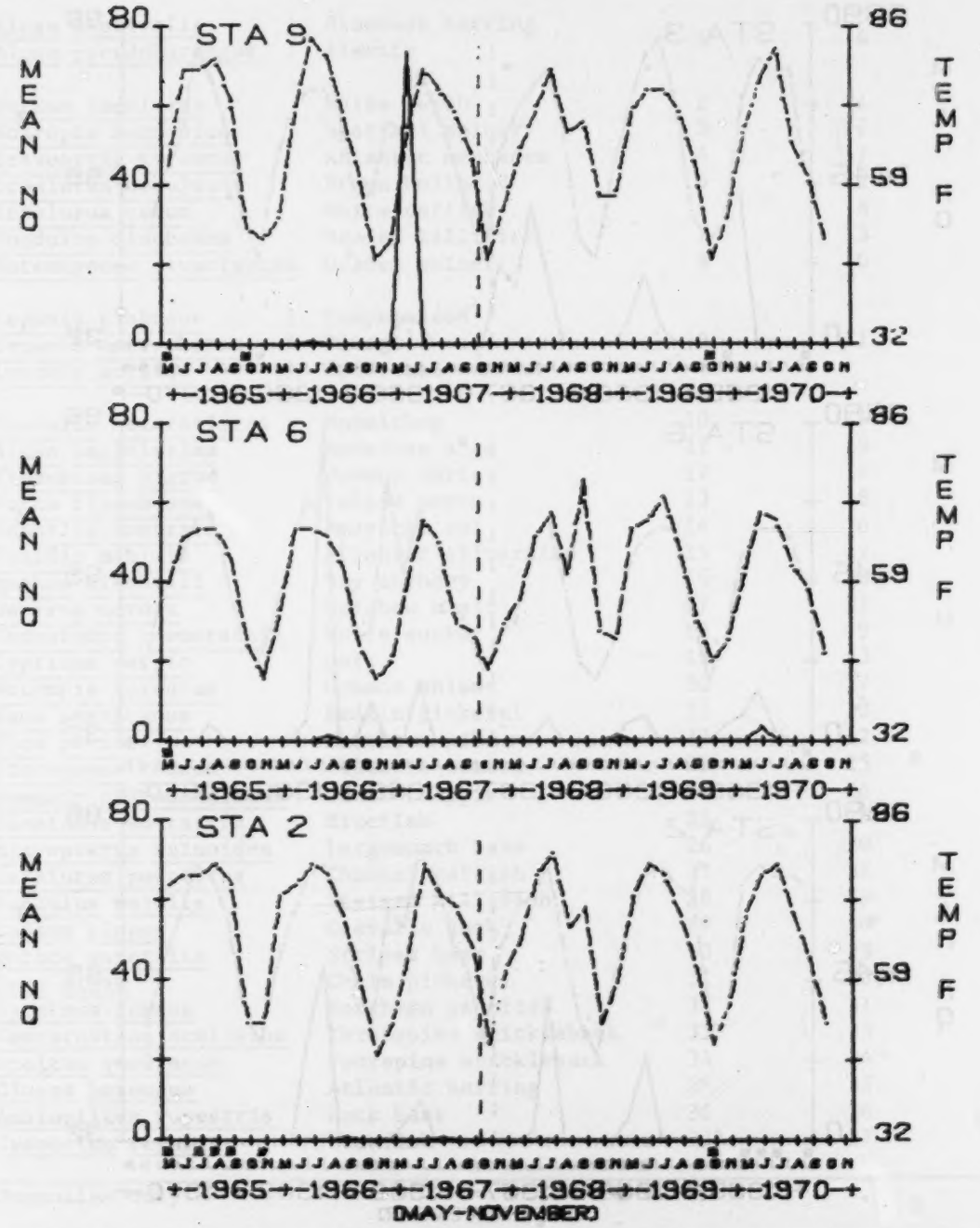
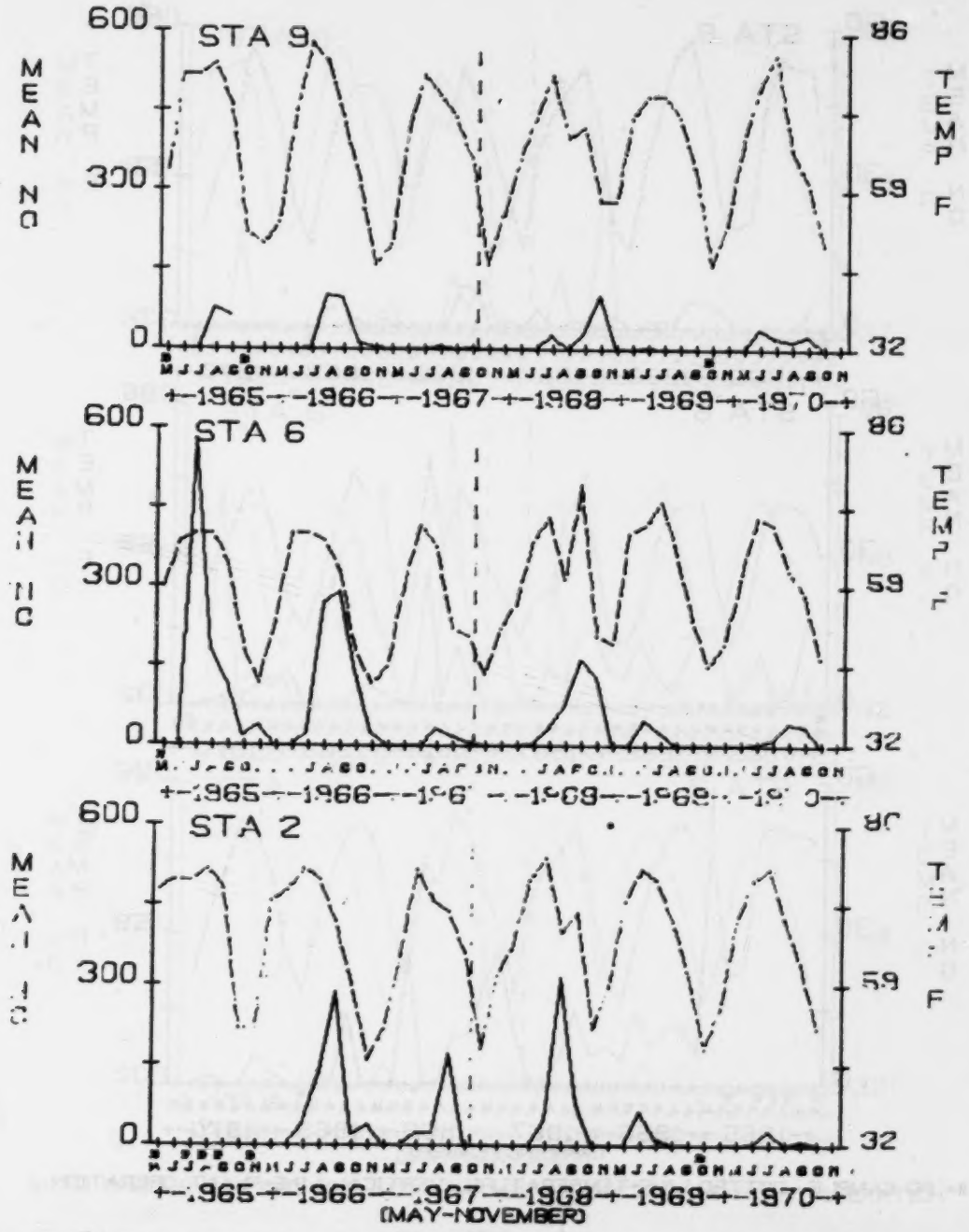


Figure 29

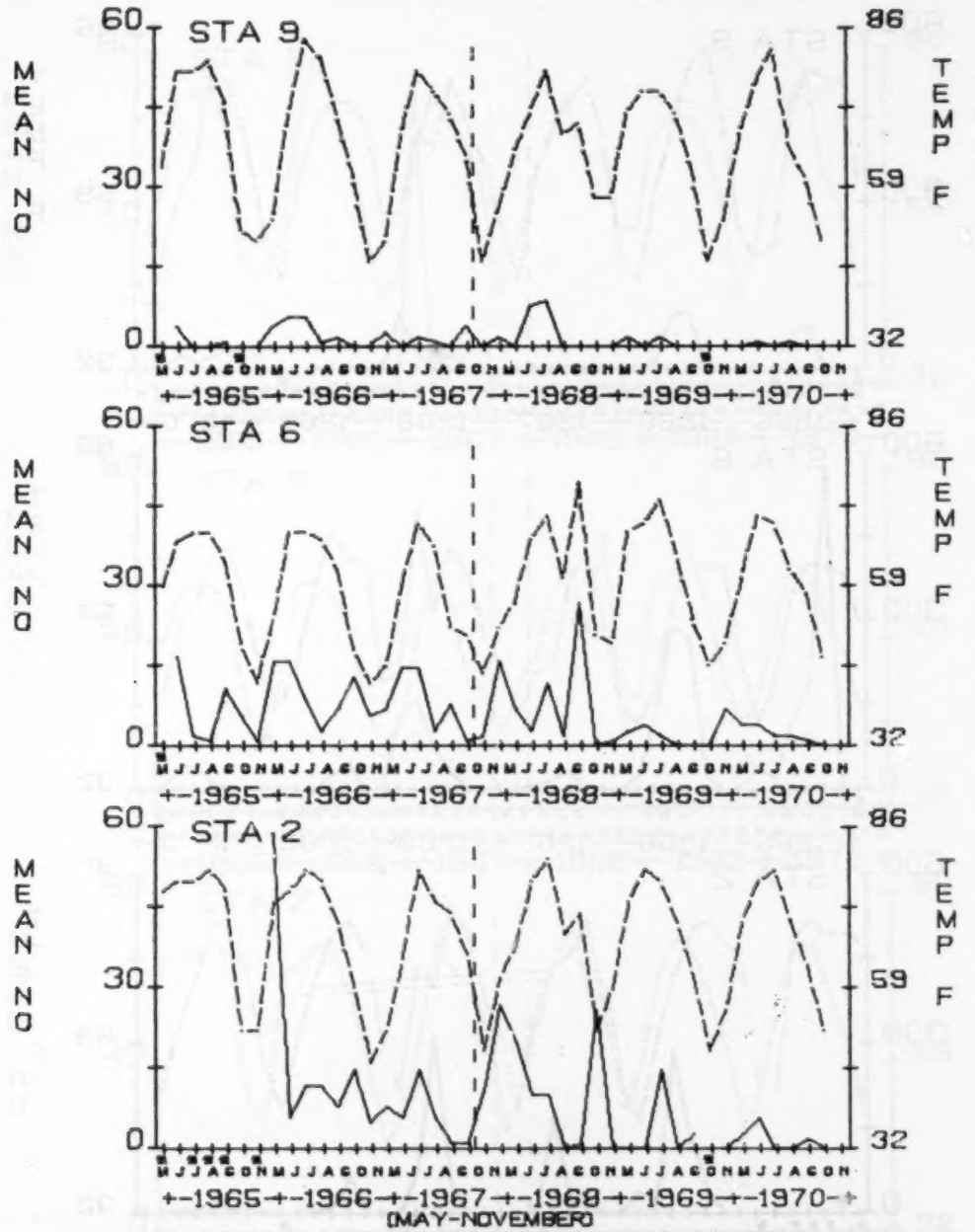
RESIDENT FISH SURVEY-M. AMERICANUS
0-YEAR



S= NO SAMPLE DOTTED LINE-TEMPERATURE VERTICAL LINE-PLANT OPERATION

Figure 30

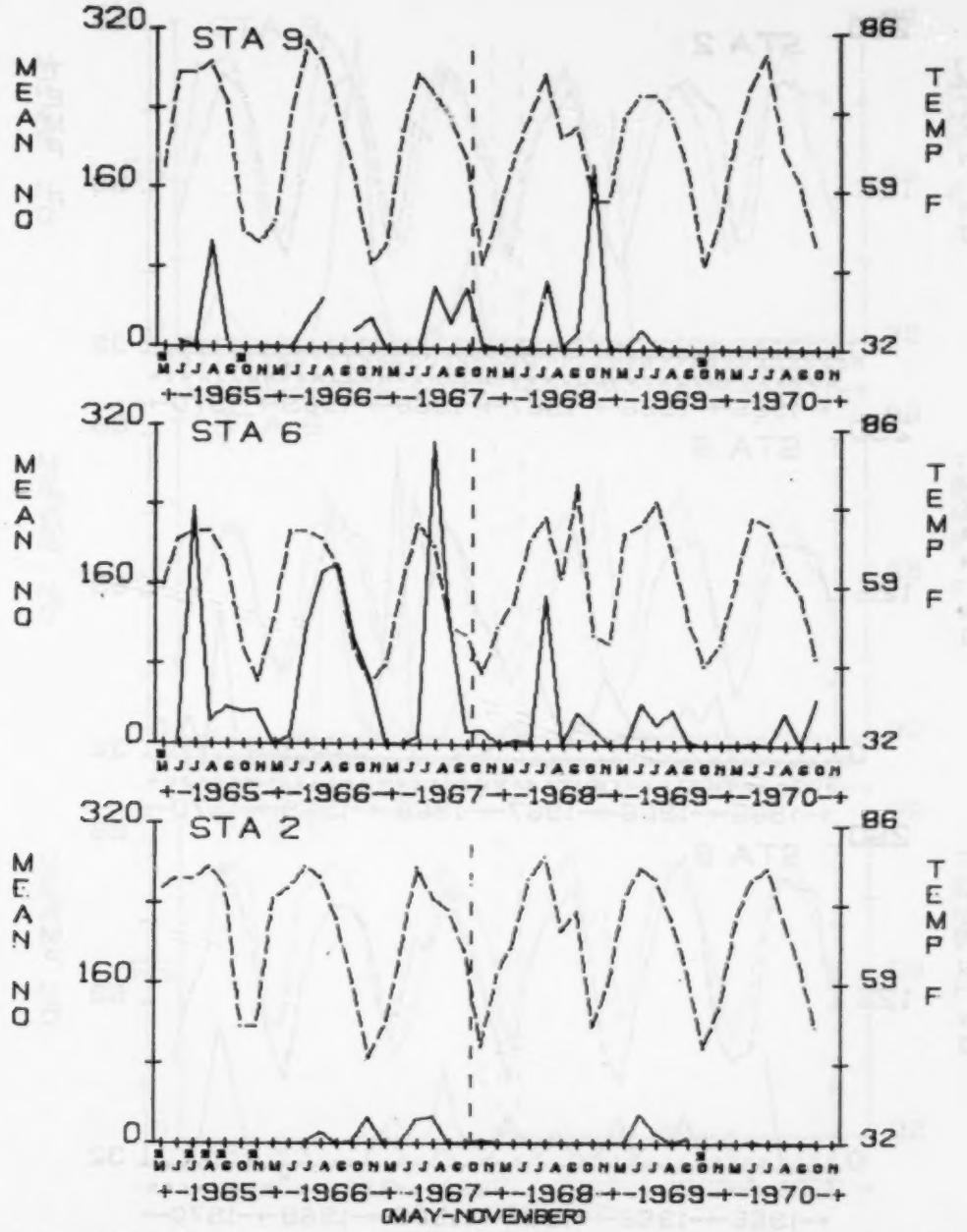
RESIDENT FISH SURVEY-M. AMERICANUS
ADULT



*- NO SAMPLE DOTTED LINE-TEMPERATURE VERTICAL LINE-PLANT OPERATION

Figure 31

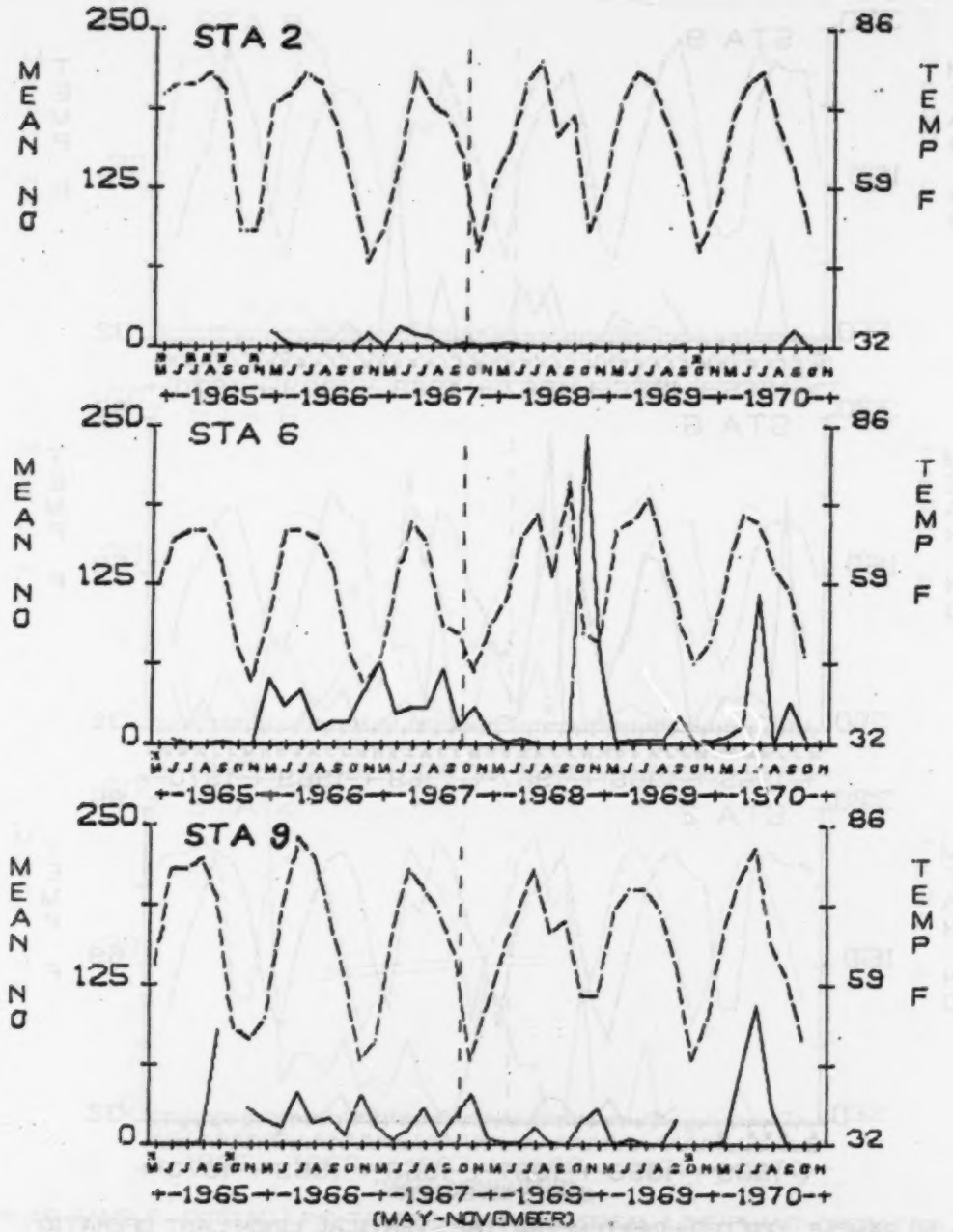
RESIDENT FISH SURVEY-N. HUDSONIUS
0-YEAR



= NO SAMPLE DOTTED LINE-TEMPERATURE VERTICAL LINE-PLANT OPERATION

Figure 32

RESIDENT FISH SURVEY-N. HUDSONIUS
ADULT



%= NO SAMPLE DOTTED LINE=TEMPERATURE VERTICAL LINE=PLANT OPERATION

Figure 33

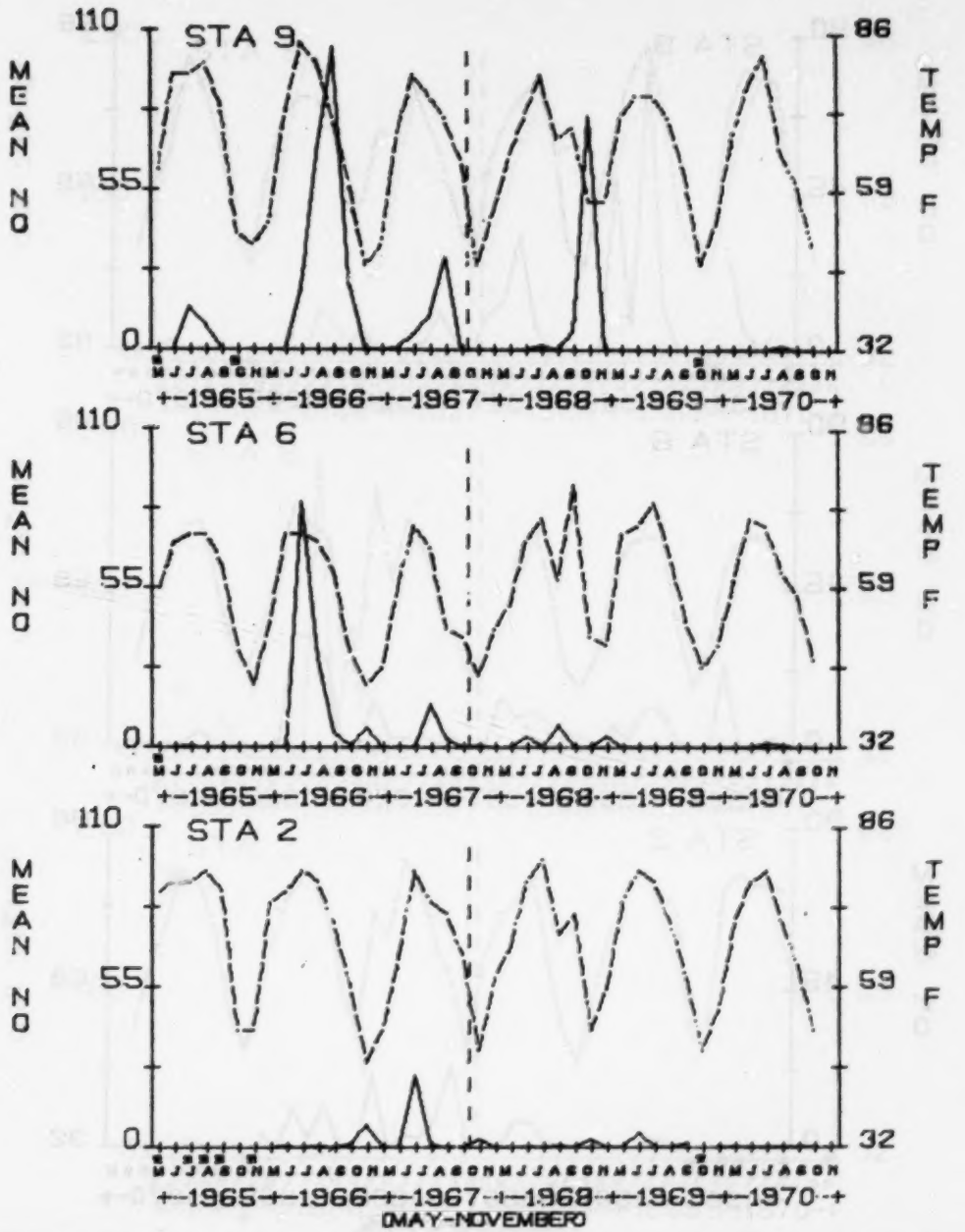

RESIDENT FISH SURVEY-I. CATUS
0-YEAR
STA 9
STA 6
STA 2
MEAN NO
TEMP F
110
55
0
86
59
32
MJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJASON
+-1965-+-1966-+-1967-+-1968-+-1969-+-1970-+
MAY-NOVEMBER
= NO SAMPLE DOTTED LINE-TEMPERATURE VERTICAL LINE-PLANT OPERATION

Figure 34

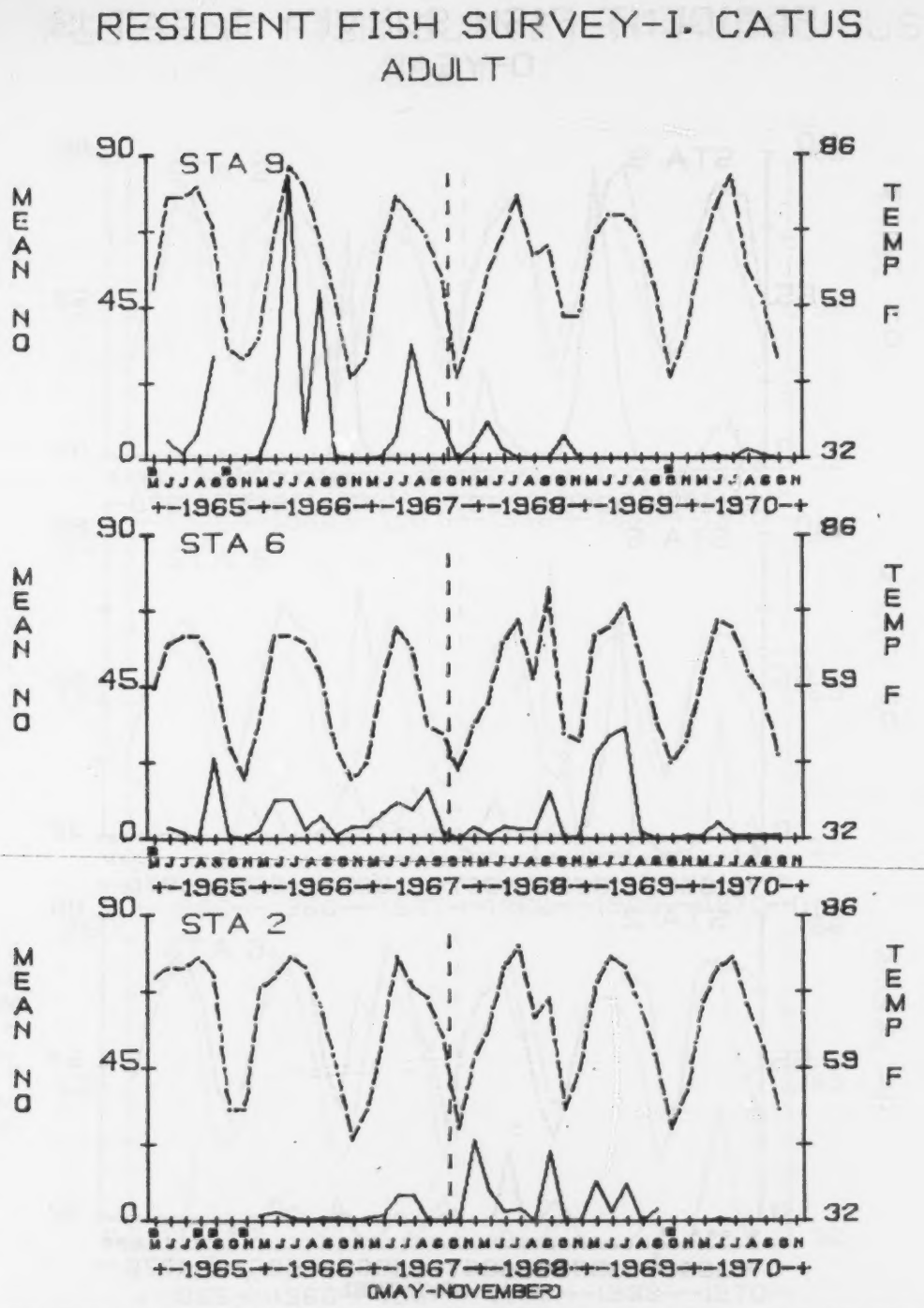

RESIDENT FISH SURVEY-I. CATUS
ADULT
STA 9
STA 6
STA 2
MEAN NO
TEMP F
90
45
0
86
59
32
+-1965-+-1966-+-1967-+-1968-+-1969-+-1970-+
(MAY-NOVEMBER)
= NO SAMPLE DOTTED LINE-TEMPERATURE VERTICAL LINE-PLANT OPERATION

Figure 35

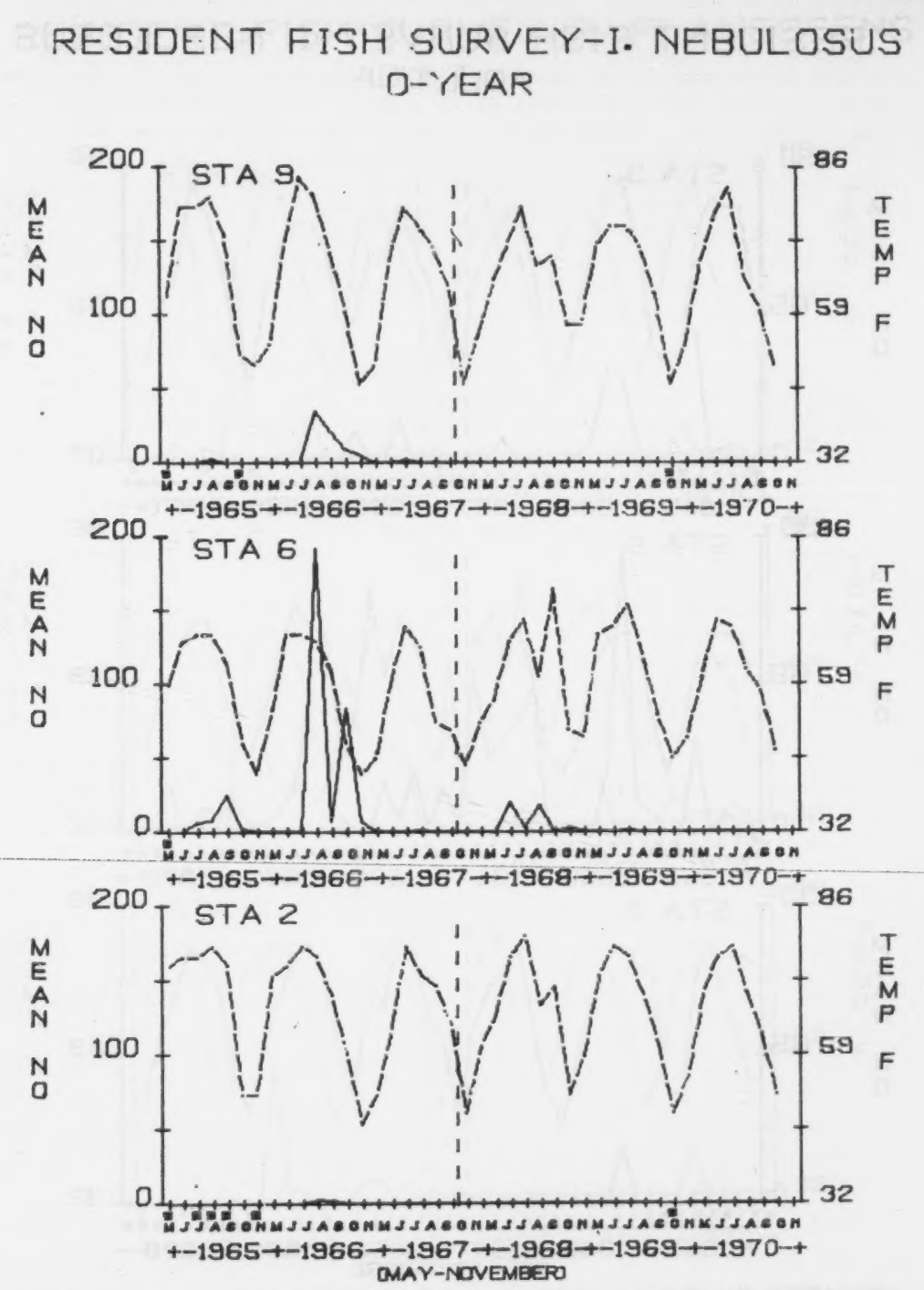
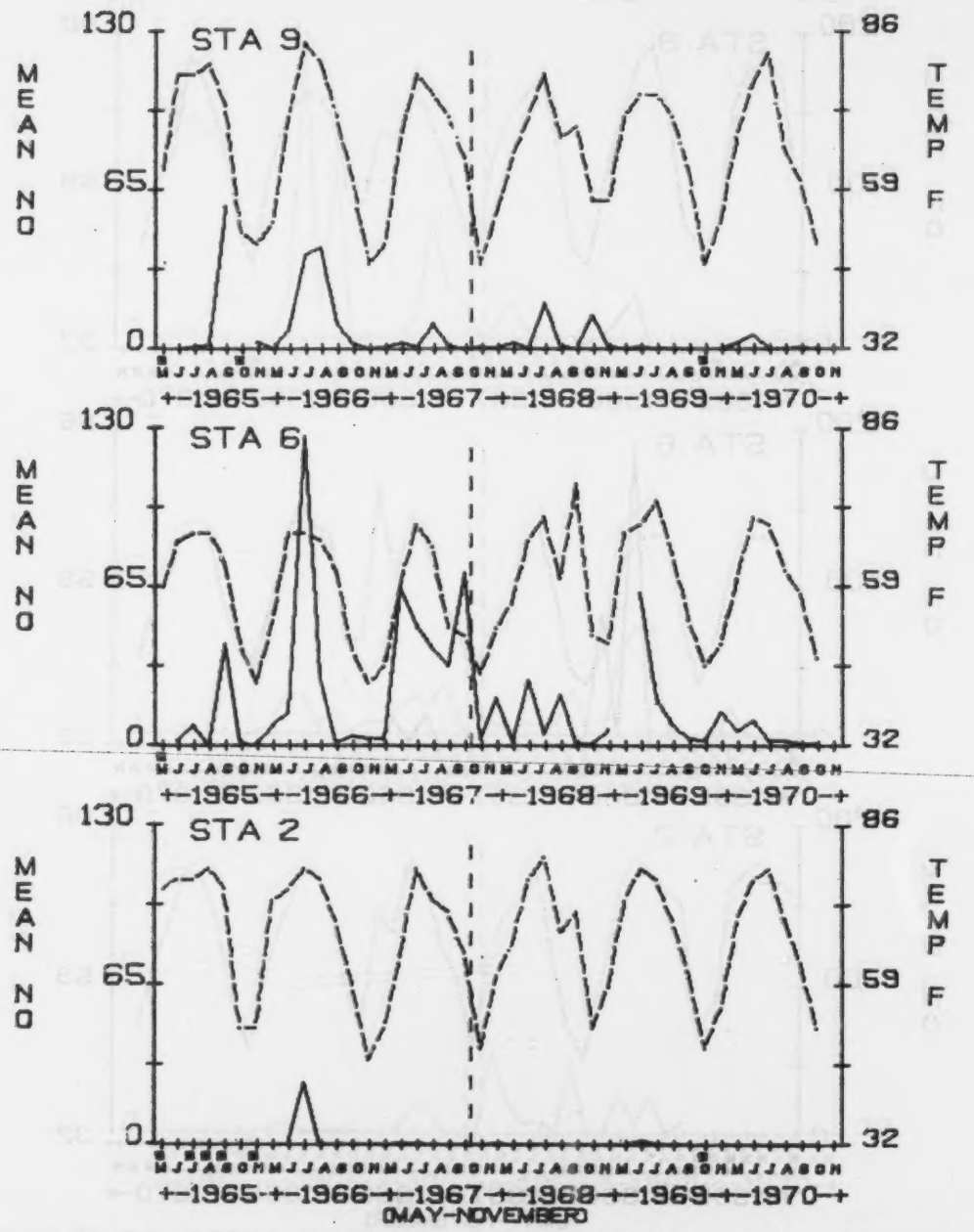

RESIDENT FISH SURVEY-I. NEBULOSUS
0-YEAR
STA 9
STA 6
STA 2
MEAN NO
TEMP F
200
100
0
86
59
32
+-1965-+-1966-+-1967-+-1968-+-1969-+-1970-+
(MAY-NOVEMBER)
S= NO SAMPLE DOTTED LINE-TEMPERATURE VERTICAL LINE-PLANT OPERATION

Figure 36

RESIDENT FISH SURVEY-I. NEBULOSUS
ADULT

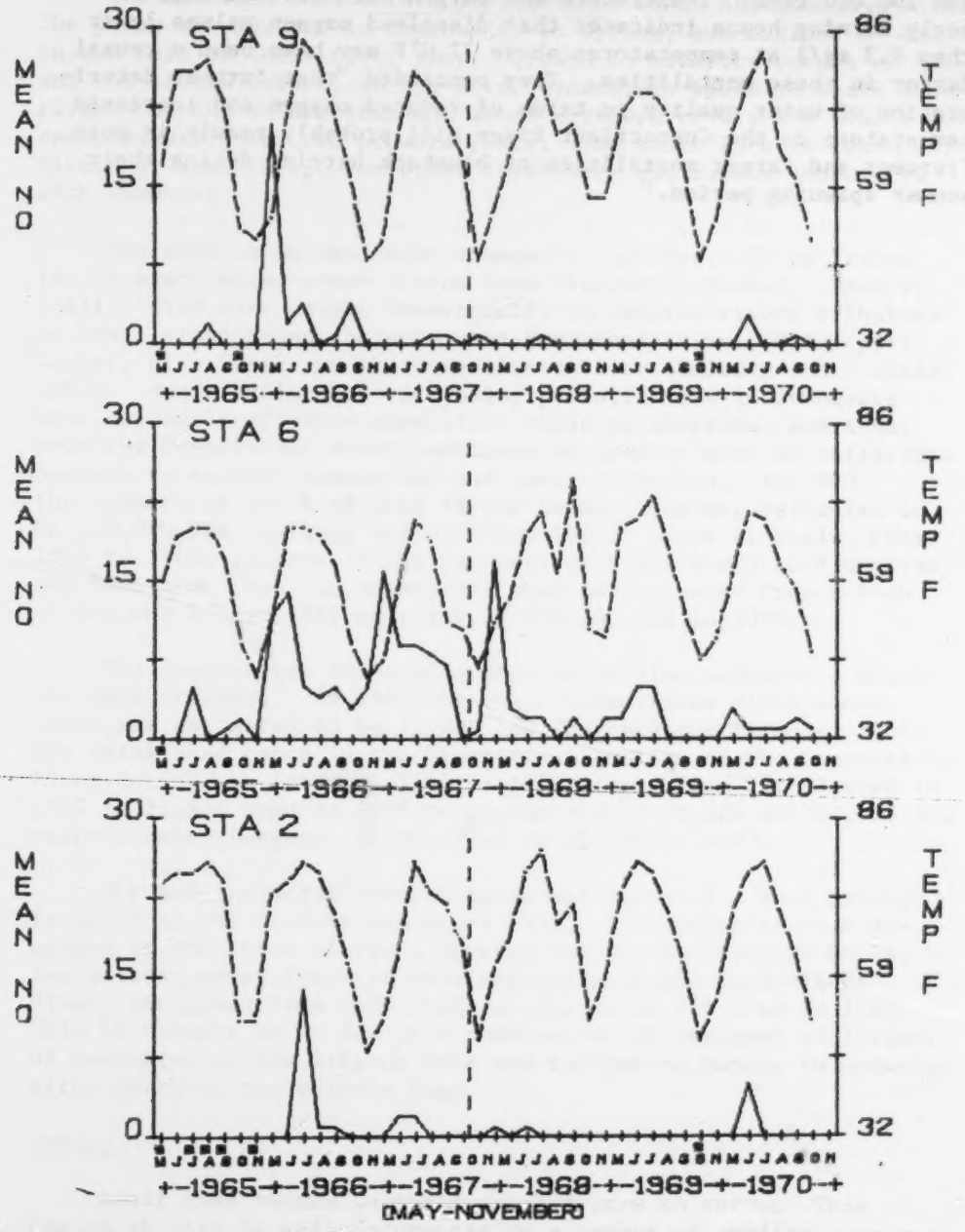


= NO SAMPLE DOTTED LINE-TEMPERATURE VERTICAL LINE-PLANT OPERATION

Figure 37

RESIDENT FISH SURVEY-P. FLAVESCENS

ADULT



* NO SAMPLE DOTTED LINE-TEMPERATURE VERTICAL LINE-PLANT OPERATION

Figure 38

Moss, Leggett and Boyd (MS in prep.) drew the following conclusions regarding four mass mortalities of blueback herring which occurred in the lower Connecticut River during the summers of 1965 to 1967. They reported that these fish kills each included between 10,000 and 100,000 fish. Temperature and oxygen data collected in the early morning hours indicated that dissolved oxygen values lower than 4.3 mg/l at temperatures above 77.0°F may have been a causal factor in these mortalities. They concluded "that further deterioration of water quality in terms of reduced oxygen and increased temperature in the Connecticut River will probably result in more frequent and larger mortalities of blueback herring during their summer spawning period."

AMERICAN SHAD, STRIPED BASS AND ATLANTIC SALMON

Life History and Connecticut River Fisheries

The American shad (Alosa sapidissima) is an anadromous species. The young are spawned in freshwater in spring, and migrate to sea in the fall of their first year. Growth to maturity occurs at sea, and the adults return, at age 4 to 5 years, to spawn in their natal river. In the Connecticut and other northern rivers the adults may spawn annually for two or more years. The adult life is spent entirely at sea, except for brief freshwater excursions associated with spawning.

The shad is an important commercial species. It is fished for in every major river system from Florida to Quebec. Historically, shad were caught commercially in several rivers tributary to Long Island Sound including the Housatonic River, Bridgeport Harbor, Pine Creek and the Connecticut River (Walburg and Nichols, 1967). Human influences, including pollution and impoundments have seriously affected several of these populations, and today only the Connecticut River continues to produce shad in sufficient numbers to support commercial and sport fisheries. In 1960 the commercial catch of shad in the Connecticut was estimated to be 420,000 lbs (Walburg and Nichols, 1967). More recently, from 1965 to 1969, records of the Connecticut State Board of Fisheries and Game show that the commercial shad catch ranged from a high of 352,000 lbs in 1965 to a low of 190,000 lbs in 1969.

The Connecticut River shad population also supports a valuable sport fishery. In 1960 the total Connecticut River sport catch was estimated to be 77,000 lbs (Walburg and Nichols, 1967). The total shad catch in the Connecticut portion of the Connecticut River during the interval 1965 to 1969 ranged from 22,693 shad in 1966 to 11,934 shad in 1969 or approximately 79,500 and 42,000 lbs respectively (Leggett, in Merriman et al, 1965-1969).

The Holyoke Water Power Company has operated a shad passage facility at the Holyoke Dam since 1955. The number of shad admitted to the reach of river between Holyoke and Turners Falls, the present upper limit of shad migration in the Connecticut River, has grown from 4899 shad in 1955 to 65,751 shad in 1970. This is thought to be due to a combination of improved efficiency of operation at the lifting site and increasing homing to spawning sites north of the Holyoke Dam.

Homing

Adult shad return to their natal rivers to spawn. This homing ability is well documented in a number of studies.

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Hildebrand and Schroeder (1928), Vladykov and Wallace (1938), Warfel and Olsen (1947), Hill (1959), Fischler (1959) and Nichols (1966) reported significant differences in morphological characters between Atlantic coast shad populations suggesting the presence of discrete spawning groups. Hammer (1942) found significant differences in juvenile body lengths at the end of freshwater residence, and differences in scale characteristics between populations native to the streams tributary to Chesapeake Bay. Talbot and Sykes (1958) reviewed the recoveries from extensive shad tagging operations conducted by the U. S. Bureau of Commercial Fisheries. They noted that no recaptures were made from a spawning ground in a river other than the one where the fish was tagged. Leggett (pers. comm.) reports similar findings from over 26,000 shad tagged in the Connecticut River since 1965. Leggett (1969) has also shown that the reproductive characteristics of individual shad populations are highly tailored to the environmental conditions in their home river. These characteristics are not thought to be plastic in the short term.

The means by which shad identify their home river are not known. In 1970 ultrasonic tracking studies were initiated to examine the orientation mechanisms employed by shad native to the Connecticut River as they approached the river mouth from Long Island Sound (Dodson et al, in Merriman et al, 1970). In this investigation reduced surface salinity was used as an indicator of the presence of the Connecticut River freshwater plume. Surface salinities ranging from 5 to 26 o/oo were recorded during the 1970 shad tracking season. The salinity at 2 meters ranged from 16 to 28 o/oo. The freshwater plume, as measured by reduced surface salinity, became fragmented and spread over a large portion of eastern Long Island Sound. The extent of the plume was maximum during the peak of the freshet.

In 1970 ultrasonic tagged shad exhibited a significant increase in swimming activity when in the influence of lowered surface salinity, suggesting a response to some element of the freshwater plume. The results of similar investigations, undertaken in 1971, while not fully analysed, reveal similar trends. These data suggest that the large freshwater plume associated with peak discharge may be an important navigational aid to homeward migrating shad.

Several investigators, working with species other than shad, have demonstrated that fish recognize their home river through olfactory clues involving volatile substances carried in the waters of the home stream. These studies have recently been reviewed by Hara (1970). It is probable that shad identify their home river by similar means. This problem is presently under investigation.

If olfactory clues are important in homing, reductions in the size of the freshwater plume entering Long Island Sound, resulting from diversion, could alter the homing ability of Connecticut River shad.

It is presently impossible to predict the minimum discharge rate required to insure adequate dispersal of chemical or other homing clues into Long Island Sound. However, some understanding of the impact of diversions in the order of 4000 cfs can be gained from a study of natural variation in discharge levels in the past. Figure 39 presents daily discharge rates at Thompsonville for the period 1965 to 1970 (USGS 1965-1970). It shows that natural yearly and daily variations in discharge rates, greatly in excess of 4000 cfs,occurred frequently. There were no obvious changes in shad abundance directly associated with these fluctuations in discharge. Tables 14, 15, and 17 present discharge rates associated with the data of the first, median and last shad captured at Old Saybrook in tagging studies conducted by Essex Marine Laboratory from 1965 to 1970. They show that between year variations in discharge rates in excess of 4000 cfs were associated with each of these dates. Finally, in 1965 and 1968, peak movement of shad into the river (approximately May 5 to May 25) occurred when natural discharge rates were near the minimum level for diversion.

Based on these observations, we predict that diversions up to 4000 cfs, with a guaranteed minimum flow of 17,000 cfs will not seriously affect the homing ability of Connecticut River shad.

Timing of the Run at Old Saybrook, Connecticut

The timing of the marine and freshwater migrations of American shad is closely governed by specific water temperatures (Leggett and Whitney ms report). The temperatures associated with the peak of the run depend upon where in the river the counts of shad are made. Lower temperature regimes were observed near the mouth of the river and higher temperatures were noted upstream on the spawning beds. In the St. Johns River, Florida, the York River, Virginia and the Connecticut River, most shad entered the rivers when temperatures were between 50 and 59°F. For these three rivers and the Columbia River, Washington, the peak movement near the spawning grounds occurred between 60 and 68°F.

Leggett (1969) documented the relationship between temperature and the timing of shad entry into the Connecticut River. He observed that shad begin to enter the river at 40 to 43°F. The catch in the commercial fishery, which operated at the river mouth, continued to increase with temperature up to 57°F (r= 0.286,

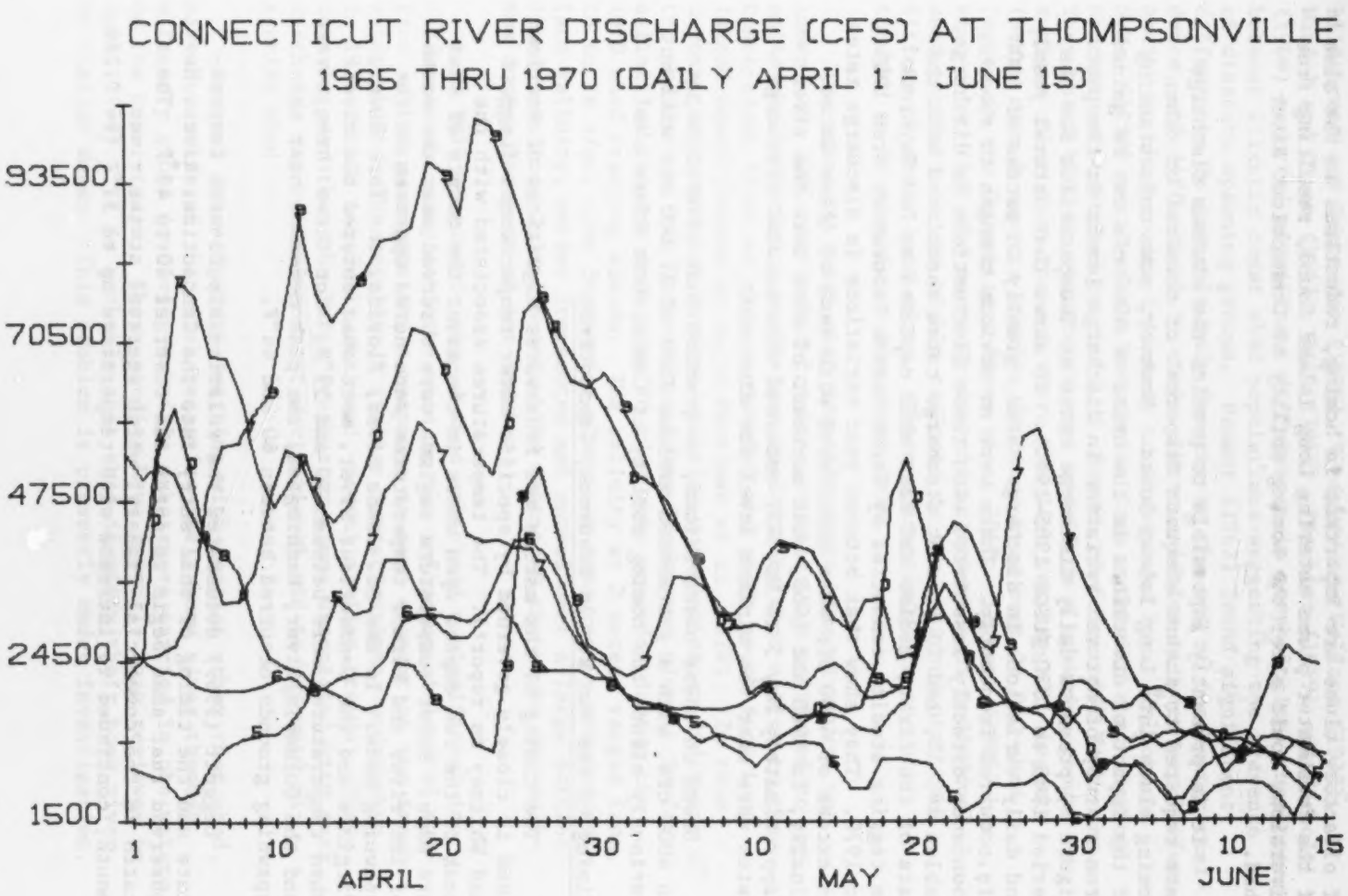
CONNECTICUT RIVER DISCHARGE (CFS) AT THOMPSONVILLE
1965 THRU 1970 (DAILY APRIL 1 - JUNE 15)
93500
70500
47500
24500
1500
1
10
20
30
10
20
30
10
15
APRIL
MAY
JUNE

Figure 39

Temperature and Flow Coincident with the First Shad Capture at Old Saybrook[1]

YEAR	DATE	TEMPERATURE (F)	FLOW (cfs)
1966	April 11	41.0	24900
1967	April 11	40.0	55600
1968	April 8	44.5	41100
1969	April 7	43.0	61300
1970	April 12	43.0	59180

[1] Temperatures at Old Saybrook to nearest 0.5 F

Table 14

Temperature and Flow Coincident with the Median Shad Capture at Old Saybrook

YEAR	DATE	TEMPERATURE (F)	FLOW (cfs)
1966	April 22	47.5	31200
1967	May 8	48.0	35300
1968	May 2	52.5	22800
1969	May 3	51.0	63100
1970	May 2	54.5	62260

Table 15

Temperature and Flow Coincident with the Last Shad Capture at Old Saybrook

YEAR	DATE	TEMPERATURE (F)	FLOW (cfs)
1965	May 28	72.5	9100
1966	May 27	62.5	19400
1967	June 2	58.0	29300
1968	June 4	61.5	22600
1969	June 2	68.5	15800
1970	May 27	61.0	19140

Table 17

d.f.= 494, $p < 0.01$). At temperatures above 57°F the catch steadily declined ($r = 0.311$, d.f.= 385, $p < 0.01$).

Leggett's initial work has been confirmed by this study. The Essex Marine Laboratory has operated a shad tagging program in the commercial fishery at the mouth of the river since 1965. In each year except 1965, netting operations were begun prior to the expected arrival of shad and were continued until few shad could be caught or until high mortality occurred which resulted from high temperatures late in the season. The first shad were captured when river temperatures ranged from 40 to 45°F (Table 14). The temperatures at which the median shad was caught varied from 47.5 to 54.5°F (Table 15). During the interval from 1966 to 1970, the mean temperatures during tagging operations were between 49.5° and 55°F (Table 16). The last shad were caught when temperatures were from 58 to 72.5°F (Table 17). It should be noted that the temperatures in Table 17 may be the result of rapid water temperature elevations which occur at this time of year and therefore may not be "preferred" temperatures for shad migration. From 1965 to 1969 catch per net hour was found to be positively correlated with temperature ($r = 0.196$, d.f.= 477, $p < 0.01$).

A 1/2°F rise in temperature may alter the timing of shad entry at Old Saybrook by hastening the initiation of water temperatures conducive to shad migration. Correlation analysis between time and temperature data taken from Figure 40, which is a graph of Essex Marine Laboratory's Station 5 temperature data, indicated a strong positive correlation ($r = .939$ $n = 232$). A regression equation was then generated into which a 1/2°F could be fitted.

$$Y = 2.31 + .254A$$

where Y = temperature

X = day

If river temperatures were increased 1/2°F, the run may start one day sooner. Since flow is usually not as low as 17,000 cfs when shad are entering the river, the possibility of a sustained 1/2°F rise due to diversion is not likely and the possible earlier entry of shad is not seen as presenting any significant consequence.

Flow

Leggett and Whitney analysed the factors regulating entry of shad into the Columbia River. They concluded that the observed correlation between the timing of the run and river discharge levels had no significance except that the run occurred after flows began to decline. Shad migrate into streams having various discharge volumes and at times when discharge in a particular stream may vary greatly. This was not thought to be characteristic of

Mean Temperature and Flow Recorded

During Tagging Operations at Old Saybrook

YEAR	TEMPERATURE (F)	FLOW (cfs)
1966	50.0	31800
1967	49.5	33900
1968	55.0	26100
1969	51.5	64900
1970	52.0	55400

Table 16

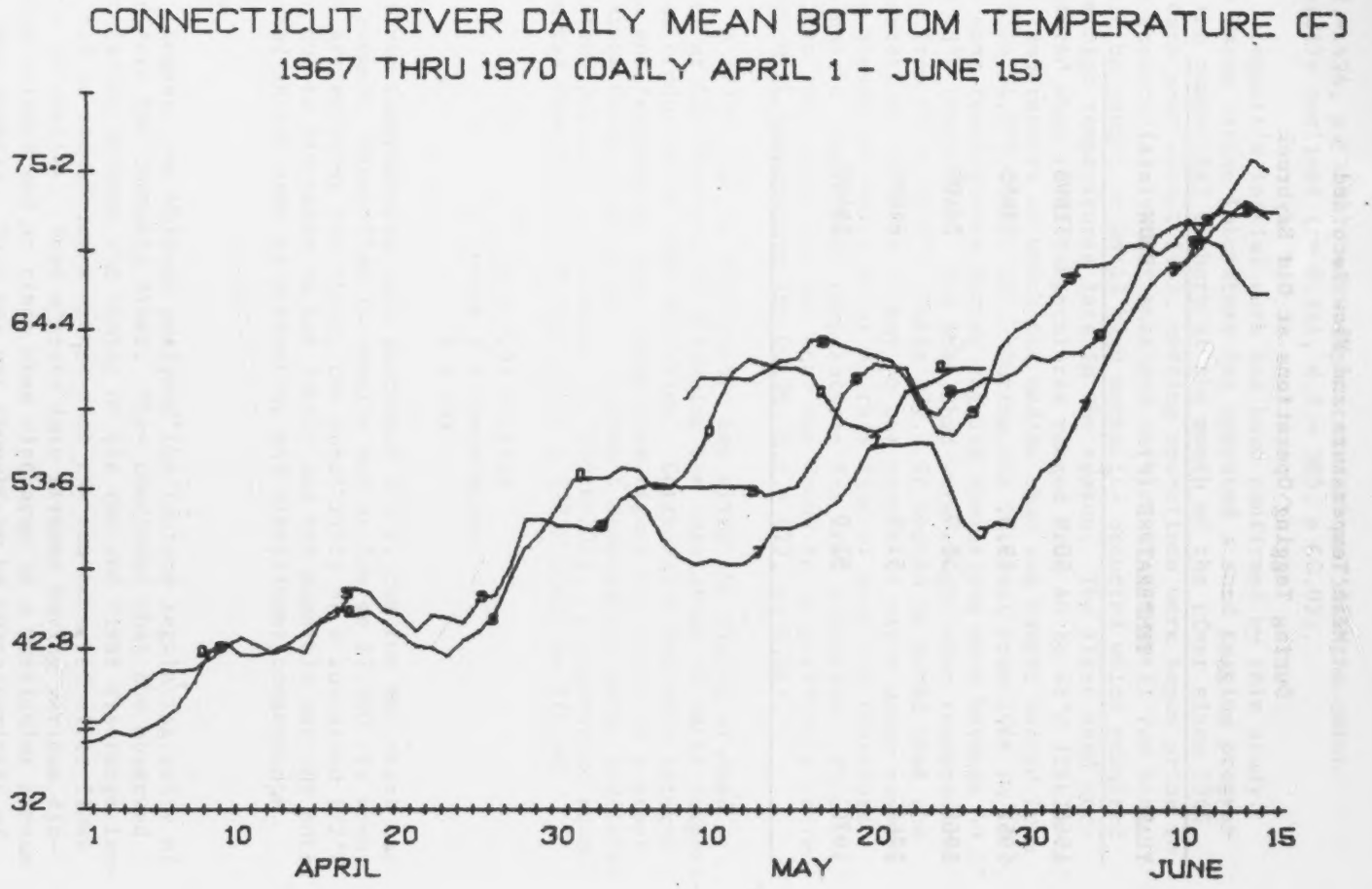
CONNECTICUT RIVER DAILY MEAN BOTTOM TEMPERATURE (F)
1967 THRU 1970 (DAILY APRIL 1 - JUNE 15)
75.2
64.4
53.6
42.8
32
1
10
20
30
10
20
30
10
15
APRIL
MAY
JUNE

Figure 40

the behavior of a flow dependent species.

In the Connecticut River, discharge volume during freshet varies greatly from day to day and on the same day in different years (Figure 39). In 1966 the first shad was caught when the flow at Old Saybrook was 24,900 cfs (Enfield Dam flow plus ten percent, Fred Ruggles, pers. comm.). In 1969 the flow was 61,300 cfs when the first shad was caught or about 2-1/2 times as great as in 1966 (Table 14). This wide variability in flow regimes may be noted also for the median capture (Table 15) and the last capture (Table 17). The mean flow was 2-1/2 times as great in 1969 (64,900 cfs) as it was in 1968 (26,100 cfs) (Table 16). From 1965 through 1969, a correlation analysis between flow and catch per net hour resulted in a negative relationship ($r = -0.094$, $d.f. = 477$, $p < 0.05$).

It is probable that the relationship between decreasing flow and increasing catch per net hour is an artifact created by the positive response of shad to rising water temperatures which occur concurrently with declining discharge volumes. Because of the large natural flow variation during freshet and the observation that shad migrate under vastly different flow regimes in each year, the diversion would not be expected to affect the timing of the shad run.

Variation in Annual Population Size

Several investigators have attempted to correlate flows and temperatures occurring one, four and five years previously with the abundance of returning shad. In the Hudson and Connecticut rivers, no correlation between shad abundance and flow or temperature was found (Burdick, 1954; Talbot, 1954; and Fredin, 1954).

Upstream Migration

It is not possible to determine the effects of altered stream flow on the rate of upstream migration of shad with the data available to date. Possible changes in the benthic community due to diversion will not impede the upstream migration of shad as the shad does not feed during the spawning run.

Arrival at the Spawning Site

The area of the shad sport fishery in Connecticut is known to be located on the main spawning grounds (Marcy, in Merriman et al, 1968). The timing of the shad run at this area was estimated by the catch reported at the state creel census area Suffield, Connecticut (river mile 52).

Temperature

Shad arrived at Suffield near the end of April when water temperatures were between 45 and 52°F (Table 18). The median catch was recorded in a 48 to 62° F range (Table 19). The mean temperatures each year were from 54 to 60°F (Table 20). The last shad was caught when temperatures ranged between 66 and 72°F (Table 21). The influence of temperature upon shad migration was determined by correlation analysis. Catch per fisherman increased with temperature up to 65°F at which time fishing success became very sporadic ($r = 0.281$, $d.f. = 56$, $p < 0.01$).

The purpose for shad migration into freshwater is to spawn. It would be futile if the timing of shad entry into the spawning area was not coincident with water temperatures conducive to the survival of eggs and young. It does not appear that 1/2°F would significantly alter the timing of shad entry onto the spawning grounds. For further information concerning spawning see pages 67 to 75.

Flow

Flow was found to vary greatly from year to year within the shad sport fishing area. The flow when the first shad was caught varied from 20,500 cfs to 63,900 cfs in 1968 and 1969 respectively (Table 18). The median catch in 1967 was made when flows were nine times greater than for the median catch in 1965 (Table 19). The mean flow for each year occurred over a 12,460 to 37,360 cfs range (Table 20). The last shad was caught when flows were from 2230 cfs to 17,200 cfs (Table 21). Although wide ranges of flow existed, an increase of catch per fisherman corresponded with a decrease in flow ($r = -0.377$, $d.f. = 356$, $p < 0.01$).

Flow is not seen as a limiting factor for the timing of the shad run in this area. Flow does have more effect upon shad fishing success in the sport fishery than in the commercial fishery because of the existence of the Enfield Dam, a 5 ft high barrier at the north end of the state creel census area. This dam for a short time tends to congregate shad seeking the sluiceway in the center of the dam (Cole Wilde, pers. comm.). Since natural flow conditions from season to season lengthen or shorten the time of shad holding at this dam without observable consequences, a possible slight increase in holding should not significantly alter the fishery or the run.

The Impact of Flow and Temperature upon Catch per Fisherman

The relationship between flow, temperature and catch per

Temperature and Flow when the First Shad was Caught at the State Creel Census Area[1]

YEAR	DATE	TEMPERATURE (F)	FLOW (cfs)
1965	April 27	46	23200
1966	April 23	48	31900
1967	April 30	45	25100
1968	April 20	52	20500
1969	April 30	50	63900

[1] Temperature at Suffield, Connecticut to nearest degree

Table 18

Temperature and Flow when the Median Shad was Caught at the State Creel Census Area

YEAR	DATE	TEMPERATURE (F)	FLOW (cfs)
1965	May 22	62	6340
1966	May 25	60	18300
1967	May 27	48	56900
1968	May 13	56	15200
1969	May 19	58	21000

Table 19

Mean Temperature and Flow During the Shad Fishing Season at the State Creel Census Area

YEAR	TEMPERATURE (F)	FLOW (cfs)
1965	59	12460
1966	57	17240
1967	54	29320
1968	60	21100
1969	57	37360

Table 20

Temperature and Flow when the Last Shad was Caught

at the State Creel Census Area

YEAR	DATE	TEMPERATURE (F)	FLOW (cfs)
1965	June 27	67	2230
1966	June 26	66	2580
1967	June 25	71	17200
1968	June 25	70	15300
1969	June 15	72	7090

Table 21

fisherman over a 5 year period was investigated by correlation analysis. A significant correlation between increasing temperature, decreasing flow and increasing catch per fisherman was observed ($R = 0.379$, $d.f. = 355$, $p < 0.01$). A multiple regression equation was then developed:

$$Y = 886.5 + 4.33A + 0.01B$$

where Y = catch per fisherman
A = temperature
B = flow

The resultant theoretical values of catch per fisherman corresponding to a 4000 cfs diversion and a 1/2° F rise in temperature were tested against the known values by chi square analysis and no significant difference was observed.

Holyoke Fish Lift

At river mile 74, the upstream migration of shad is blocked by the Holyoke Dam. Shad have been passed over this dam since 1955.

Temperature

Leggett and Whitney found that the timing of the shad run at Holyoke was temperature dependent. From 1955 to 1969, they noted a positive correlation between the time of median shad passage and the time the temperature first exceeded 65°F ($r = 0.758$, $d.f. = 13$, $p < 0.01$). They also noted that the peak of the run occurred within a narrow temperature range (64 to 71°F), and that 86.6% of the observations were within the 66 to 70°F range.

Flow

During 1968 and 1969, Watson (1970) was able to correlate lift effectiveness with flow, rainfall, temperature and the number of lift days. Of these he said that flow appeared to be most important. When flows were high, water passing over the dam detracted from the influence of the lift attraction water reducing the efficiency of the lift.

It seems likely that passage of shad at Holyoke is controlled by both temperature and flow. Temperature appears to be the controlling mechanism influencing shad abundance at Holyoke while flow regulates the efficiency of the lifting facility. Diversion could result in passage of shad slightly earlier in the season.

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Weight Loss and Post Spawning Mortality

Shad do not feed during their freshwater migration. They must utilize body reserves as an energy source for the migration. Leggett (MS 1971) estimated that 45 to 68% of the total body weight (gonads excluded) may be required during their freshwater residence.

The shad is a poikilothermal animal. Its rate of metabolism increases with the temperature increase of the environment. Brown (1957) reported that in most fish species the rate of utilization of body reserves doubles with every 18 F rise in temperature. Therefore, shad migrating in late May, when temperatures are higher, may utilize approximately twice the energy as shad migrating in mid-April when temperatures are lower.

Leggett (1969) related increased water temperature with post spawning mortality. Shad entering the Connecticut River at temperatures above 57°F had a statistically higher rate of mortality than did shad entering at lower temperatures. This temperature-mortality relationship is verified by observation of shad populations in other river systems. In the St. Johns River, Florida, water temperatures seldom fall below 57°F and all shad die after spawning. In shad populations spawning in river systems farther north, the proportion of repeat spawners increases with latitude. This suggests that post spawning mortality is reduced in rivers where migration can occur at lower temperatures. In the Connecticut and York rivers, there are, in general, more repeat spawning males than females. This is thought to result from the earlier entry of males into the river, thereby resulting in migration at lower temperatures.

Because large mortality occurs in the southern range of the shad, it should not be concluded that high water temperature has no bearing on the perpetuation of a shad population. Leggett (1969) has reported that these southern populations are able to sustain themselves through adaptation to environmental conditions. That is, the large mortality is offset by a production of more eggs per ovary. Therefore fewer repeat spawners are necessary to perpetuate the run. This adaptation is not a feature of our Connecticut River shad and increased temperature may be detrimental.

More experimentation is needed to determine the exact relationship between weight loss and post spawning mortality. It is not presently known whether shad will respond to increased water temperature resulting from diversion by entering the river system earlier. If shad do not enter the river earlier, it still seems

unlikely that additional mortality would occur because the ranges of preferred temperatures by which shad move upstream allow for a ½°F rise in temperature to be obscured. In a very warm year, this ½°F rise may add to already unfavorable temperature regimes resulting in increased mortality.

Striped Bass (Morone saxatilis)

Striped bass occur to a limited extent in the Connecticut River as far north as the Enfield Dam. Merriman (1941) found stripers entering the Niantic River, Connecticut when the water temperature was 42.8 to 45.5°F and leaving at about the same temperature in the fall. He also found the maximum temperature tolerance for this species in New England waters was 77.0 to 80.6°F.

It does not appear that the proposed diversion would adversely affect the striped bass utilizing the river because water temperatures naturally approach or exceed their maximum tolerance level and no mass mortalities have been evident.

Talbot (1966) reported that stream discharge does not seem to be a limiting factor except during spawning when large volumes of moving water, either as freshwater runoff or tidal action, are required to keep the eggs in suspension. Striped bass probably do not spawn in the Connecticut River (Barton C. Marcy and George Maltezos, pers. comm.).

A diversion of 4000 cfs is not seen as a hindrance to utilization of the Connecticut River by striped bass because they are able to maintain themselves in rivers of much smaller discharge and the importance of an adequate flow regime for spawning is probably not necessary.

Atlantic Salmon (Salmo salar)

A program for the restoration of Atlantic salmon to the Connecticut River is currently in progress. Preliminary stocking experiments have begun. Robert A. Jones (pers. comm.) reported that in approximately two years sufficient smolts will have been stocked for returning salmon to become evident. The timing of salmon entry into the river is not known. Historically the run was in the early spring. The main spawning area will probably be near the White River in Vermont with some incidental spawning in the Salmon and Farmington rivers. Since spawning is projected to take place above the diversion site or in tributary streams not affected by diversion, it seems unlikely that the diversion would affect spawning. The effect of diversion on Atlantic salmon

homing or upriver migration can not be predicted at this time.

RECOMMENDATIONS FOR FURTHER STUDIES

The sampling program upon which the shad report is based was not designed to measure the effects of diversion. It is therefore recommended that several phases of this problem undergo further investigation in order that the impact of diversion might be more accurately predicted.

(1) The maximum amount postulated to be diverted under the conditions of this study was 4000 cfs in a 24 hr period with a control flow of 12,000 cfs at Montague City. If greater diversion rates were considered, the potential environmental impacts of these rates would be necessary.

(2) The mechanism of shad homing, which is presently poorly understood, should be fully known before large quantities of Connecticut River water are diverted.

(3) The effect of flow upon relative abundance, population size and the rate of upstream migration should be quantified as precisely as possible.

(4) The relationship between weight loss and post spawning mortality and temperature should be determined.

(5) The impact of the diversion upon the salmon restoration program should be fully investigated in cooperation with the Connecticut Department of Environmental Protection.

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APPENDIX F

IDENTIFICATION AND ASSESSMENT OF SOCIAL AND ECONOMIC IMPACTS -- CONNECTICUT AND MILLERS RIVER BASIN DIVERSIONS

Abt Associates, Inc. prepared this appendix on the social and economic impacts of the diversions for the New England Division, U. S. Army, Corps of Engineers. The report attempted to identify and assess the various social and economic impacts so that the diversion projects can be evaluated in the broad context of social objectives as well as traditional benefit/cost analysis. In the analysis, two opposite occurrences are evaluated: one assumes that both Northfield and Millers River projects are implemented; the other assumes that no project is built to meet the added demands. Generally, the study effort was to distinguish short- and long-term changes as they relate to basin communities and to the water-short communities. Short-term impacts were found to be project-specific. The long-term changes relate more to the shortage or availability of water. The data and analysis provided in this appendix was then transformed in the Project Impact Analysis section of the main report to benefits and costs associated with the specific project.

Identification and Assessment of Socioeconomic Impacts of the Connecticut & Millers River Basin Diversions

Submitted to:

New England Division
Corps of Engineers

Contract No. DACW33-72-C-0013

AAI #72-40

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1.0 BACKGROUND AND APPROACH

[Once] we more or less told the citizens what we were going to do, then went ahead and did it. That world has come to an end.

-Thomas N. Urban, Mayor
Des Moines, Iowa

1.1 Objectives

This report is a part of an altogether healthy development in water resource planning. Through a series of highly educative trial and error experiences in the water management business, the water management professional has come to recognize that economic efficiency by itself is a poor measure of quality and too limited a perspective on the decision-making process which commits substantial public monies to major alterations of the natural environment. Increasingly, major public works projects are being planned and evaluated in the broader context of social objectives: ecologic integrity, human betterment, and other non-marketed outputs heretofore excluded from traditional benefit/cost reckonings. A part of the Corps of Engineer's NEWS Study, the diversions to Quabbin Reservoir from the Connecticut Basin are the subjects of just that kind of new scrutiny.

Therefore, as inputs to the comprehensive evaluation of the Northfield Mountain and Tully Complex Projects, we are concerned here with the social and economic impacts they will have on the populations affected. Specifically, our task is to:

1. Identify changes attendant on the Northfield and Tully diversions that will affect human populations in the immediate supply area and among potential receivers, and
2. Quantify or characterize those changes wherever possible in terms of magnitude, direction and duration.

Outside the scope of our work is the evaluation of change; that is, whether an impact is to be accounted as positive or negative. Such judgmental considerations are properly the province of the project designers and other actors having a stake in their implementation. However, the objectives along which they will evaluate are not completely unknown. Where this analysis can provide useful insights into the attitudes and probable stances of concerned groups, it shall do so.

1.2 Study Elements

To impose some rational structure on the welter of factor pairs involved in impact analysis, the research has been structured matrix-fashion. The columnar elements are the diversion projects themselves - Tully, Priest Brook, and Tarbell Brook as one set, and Northfield Mountain as the other - considered under alternate implementation scenarios: go and no go.[1] The rows accommodate, respectively, geographic elements (suppliers and receivers) and the impact categories which represent different aspects of community activity (education, manufacturing, transportation, etc.). By considering the projects with respect to each relevant impact category and the locus of their effects, we can begin to fill cells of the matrix and distinguish the broad contours of economic and social change.

Obviously, not every possible combination is equally important. In some cases the magnitude of change in a given cell is so small as to be insignificant. In others, a forecast change may be small but long-lived, thus overshadowing a larger but more ephemeral effect. Generally, the effort is to distinguish short- and long-term changes for each impact category as it relates to suppliers and receivers. Short-term has been defined as the five-year term required for construction. Thus, impacts so accounted are project-specific. Long-term encompasses changes falling outside that limit and related less to the specific works proposed than to the shortage/availability of a quantity of water equal to that diverted. In both cases the definitions apply without regard to

---

[1] Because this document is not intended as a survey, lengthy discussions of the physical aspects of the projects will be omitted. It is assumed that the reader is familiar with the proposed construction; by site, by volume diverted, by cost and so on. In considering this two-part project, primary attention has focused on the Tully Complex rather than on Northfield, because it is the area in which the Corps has decision-making authority. Northfield is to be developed under the aegis of the Metropolitan District Commission, whose behavior and accountability to public bodies is quite different in nature. Nonetheless, because the two projects are akin in size and technique and because they must be implemented together to provide the additional 120 mgd yield required of Quabbin, they are considered here as a pair.

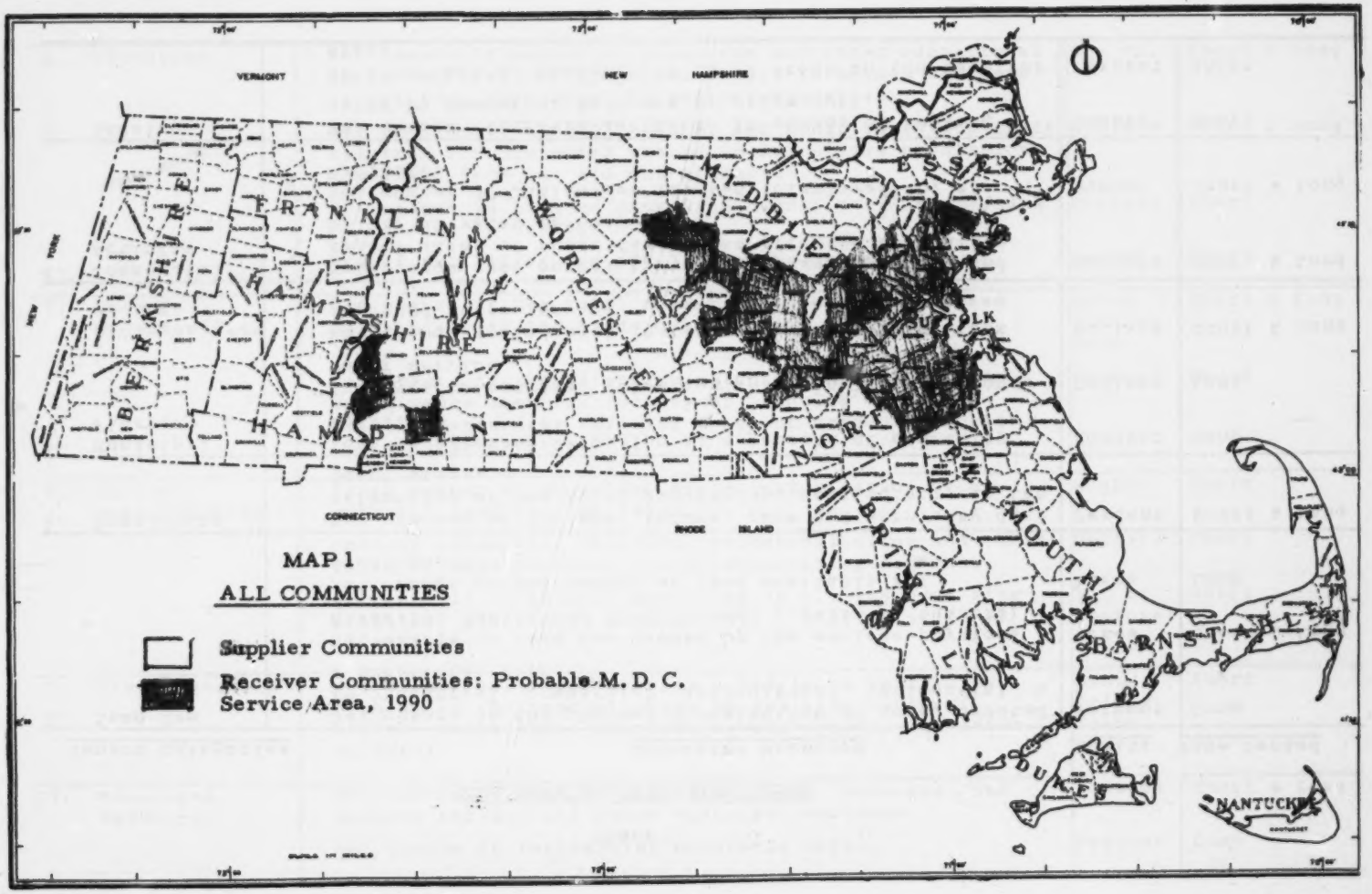
real time; that is, the five-year period begins to run whenever construction commences. It would be unreasonable to consider our findings valid if implementation is delayed much beyond the end of this decade. But the authorization process, not to mention the planning process, has tended to become longer rather than shorter, and 8 years between a decision to build and actual groundbreaking is not improbable.

The universe of communities affected numbers eighty-six, as indicated on Map 1. Of that number eighteen were considered potential suppliers and the balance as receivers. This latter category was broken down further by type of M. D. C. service: wholly served, partially served, and potentially served (no option). Communities with other water supply options were considered to constitute the extreme upper end of 1990 demands on the Quabbin-Wachusett system and were excluded from the study. Ultimately, seven suppliers and ten receivers were the subjects of detailed analysis.

Impact categories used in the study are shown in Table 1. It should be emphasized that the measures they include were developed in advance of any application to an actual project. As experience has shown, in many cases they are at too fine a level of detail for the data available.

Insofar as possible, profiles of sample communities were built in the same format as impact categories.[2] Extrapolations of these qualitative and quantitative data serve as the "without project" baseline. Over the short term, baselines are merely a continuation of trends noted in the profiles. For example, it has been assumed that in- and out-migration patterns will continue, that no catastrophic economic shifts will occur and that existing regulatory policies and jurisdictional lines will remain unchanged. Over a time horizon extended to fifty years, however, anticipated development is less clear. However, we have made use of the best projections available. Specifically, population, water use, and development expectations have been taken from the available Master Plans of cities

[2] See Appendix III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ESSEX
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NORFOLK
BRISTOL
PLYMOUTH
BARNSTABLE
DUKES
NANTUCKET
MAP 1
ALL COMMUNITIES
Supplier Communities
Receiver Communities: Probable M. D. C. Service Area, 1990

TABLE 1

SOCIOECONOMIC IMPACT MEASUREMENT

Impact Categories	Suggested Measures	Units	Time Period
1. Land Use	Net change in the percent distribution of acres devoted to industrial, commercial, agricultural, residential, & recreational uses.	Percent	Long
	Net change in land use caused by the various physical diversion facilities (e.g., dams, pipelines, tunnels).	Acres	Short & Long
	Net change in the amount of land available for development.	Acres	Long
2. Population	Net changes in the age, income, race and ethnicity distributions of the local population, particularly in the donor areas.	Percent	Short & Long
3. Municipal Finance	- Loss of assessed valuation as a percent of community total.	Percent	Long
	Increase in assessed valuation resulting from improved water service.	Dollars	Long
	Net change (gain/loss) in tax revenue resulting from improved water service.	Dollars	Short & Long
4. Commercial Activity	Net change over normal trends in gross wholesale and retail sales of those facilities affected by availability of water resources.	Dollars	Short & Long
	Net number of businesses located (displaced) by a facility.	Number	Short & Long
5. Housing	Net change (increase/decrease) in number of housing units by number of bedrooms by price (OR).	Number	Short
	As a percent of community's total stock in the receiver area.	Percent	Short

6. Education	Net change in amount of classroom and other educational space required for projected change in school-age population resulting from in- and out-migration.	Sq. Ft.	Short & Long
	Net changes in cost of teacher and other education staff required for projected change in school-age population resulting from in- and out-migration.	Dollars	Short & Long
	Net change in cost of providing school services because of changes in busing.	Dollars	Short
	Use of facilities for educational programs.	Day/Yr.	Short
7. Leisure Opportunities	Net change in the total number of acres of parks and playgrounds in the Study Area.	Acres Visitor Days	Short & Long
	Net change in the extent to which planned recreation space meets American Society of Planning Officials planning standards relating types of space to population characteristics.	Percent	Short
8. Cultural Opportunities	Total number of churches, historical sites or other cultural institutions taken.	Number	Short
	Cost of relocating churches, historical sites and other cultural institutions, minus compensating payments.	Dollars	Short
	Increase in locational amenities (e.g., improved site planning, additional parking, etc.,) as a result of relocation.	No. of Improvements	Short
9. Transportation	Net change in travel time as a result of facilities from major residential areas to activity centers: health, commercial, recreation, employment, education, cultural.	Min./ Trip x Trips/ Day	Short
10. Municipal Services	Net change in cost of providing water, sewerage, and garbage service and other municipal services.	Dollars	Short & Long
	Net change in residential insurance rates.	Percent	Long

11. Security	Number of positive and negative statements about the opportunities for system failure, as revealed by a content analysis of local news media.	Number	Short & Long
12. Community Image	Changes in property values adjacent to supply facilities	Dollars	Short & Long
	Number of positive and negative statements about the community as revealed by a content analysis of local news media.	Number	Short & Long
13. Community Cohesiveness	Total number of community, regional, statewide and national groups taking a position (making a public statement) for or against the project.	Number	Short
14. Citizen Involvement	Total number of community, regional, statewide and national groups involved in the planning of the project, times the level of their involvement, according to the following scale of increasing involvement: 1. Attendance at hearing; 2. citizen opportunity to critique plans at public meetings; 3. periodic workshop planning sessions with community representatives; 4. community advocate planner participated on equal basis with technical staff in all planning activities; 5. appointment of arbitrative hearing officer who makes final decision in case of dispute between community & Army Engineers.	Weighted No.	Short
15. Institutional Involvement	Total number of jurisdictions involved in the totality of the construction process for a water supply facility.	Number	Short & Long
	Number of applications submitted to the M.D.C. for water supply service by cities and towns; disposition and frequency of refusal.	Number	Short & Long
16. Economic Stability	Net change in income resulting from construction and related activities.	Dollars	Short & Long
	New increase in private investment.	Dollars	Short & Long

17. Real Income	Net change in per capita income.	Dollars	Short & Long
	Net change in tax assessments.	Dollars	Short & Long
	Net change in regional net income.	Dollars	Short & Long
18. Employment	Number and type of jobs created/lost.	Number	Short & Long
19. Industrial Activity	Change (increase/decrease) in number of industrial establishments.	Number	Short & Long
	Change in productivity indices.	Dollars	Short & Long
20. Agricultural Activity	Change (increase/decrease) in number of farm acres.	Number	Short & Long
	Change in production per acre.	Dollars	Short & Long

and towns affected. Where no such data were available, projections of economic activity are our own. In all cases, impacts are defined as deviations from the no-project baseline.

Engineering plans were made available by the Corps in the form of location maps and site drawings. To relate them to impact categories, it was first necessary to interpret them in terms of labor demands, capital expenditures, and physical alterations of specific sites as they relate to human activity. Only then could the impact measures developed become applicable.

1.3 Methodology

Because individual treatment of each of the eighty-six communities (supplier and receiver) affected by the proposed projects was never considered feasible within the dollar and time constraints of our study, it was necessary to limit the number investigated. Therefore, a computerized clustering exercise was performed which grouped communities according to sixteen descriptors:

- Present Population
- Projected Population
- Population Growth
- Population Density
- Employment
- Median Income
- Present Water Demand
- Projected Water Demand
- Status of M. D. C. Service (served, non-served)
- Total Industrial Demand
- Restrictions on Consumption (yes, no)
- Supplier or Receiver
- Future M. D. C. member
- Present M. D. C. Member
- Served Non-Member
- Have No Opinion

Next, one element from each of the sixteen resulting clusters was chosen for further study. In the subsequent data gathering effort, it became clear that not every sample community had the data required to establish competent socioeconomic profiles, or, more importantly, Master Plans from which to extract expectations of future development. Supplier towns, with the exception of Greenfield, were particularly data-poor. Indeed, they were omitted from a second Euclidian distance clustering program run only for the sixty-six receivers and with descriptors modified to eliminate collinearities in the input data.[2]

- Growth rate, 1960 - 1970
- Ratio of total employment to population, 1970
- Ratio of manufacturing employment to total employment, 1970
- Median income, 1970
- Per capita water consumption, 1970

It appeared from preliminary work that long-term economic impacts were going to be most important in receiver communities. Therefore, the variables chosen for clustering were restricted to economic factors suggestive of uniform economic structure. The outputs of the exercise follow:

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[2] Fred L. Bookstein: A Note on a New Algorithm for Multi-dimensional Clustering, Xerox. All calculations were performed at the Harvard Computing Center.

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Cluster 1.

Elements: Arlington, Revere*, Saugus, Winthrop, Weymouth

Representative and Descriptors:

Revere*

- Low-income area
- Urban/Boston satellite, North
- Largely residential
- Commercial economy
- Stagnant or little growth potential
- Low water user
- MDC receiver

Cluster 2.

Elements: Belmont*, Brookline, Milton, Swampscott, Lincoln, Lexington, Newton, Nahant, Needham, Wellesley

Representative and Descriptors:

Belmont*

- High-income area
- Urban/Boston suburb or satellite
- Residential
- Commercial economy
- Moderate growth rate
- Low water user
- MDC receiver

Cluster 3.

Elements: Boston,* Cambridge, Maynard

Representative and Descriptors:

Boston*

- Low-income to poor area
- Urban/city core
- Increasingly less residential
- Mixed economy; larger proportion commercial
- Stagnant to negative growth rate
- High water user
- MDC receiver

Cluster 4.

Elements: Chelsea, Everett, Peabody*, Clinton, Chicopee, Ashland, Woburn

Representative and Descriptors:

Peabody*

- Low-income area
- Urban independent/North Shore
- Highly industrial
- Moderate growth rate
- High water user
- MDC receiver (very small % of total consumption)

Cluster 5.

Elements: Lynnfield, Marblehead, Weston, Winchester, Southborough, Dover, Holbrook, Medfield*, Stowe, Westwood

Representative and Descriptors:

Medfield*

- Moderate or middle-income area
- Rural/Southwest of Boston
- Largely residential
- Mixed economy; moderately industrial
- Stagnant or low growth potential
- Low water user
- Not an MDC receiver

Cluster 6.

Elements: Malden, Medford*, Somerville, Stoneham, Lancaster

Representative and Descriptors:

Medford*

- Moderate or middle-income area
- Urban/Boston satellite or suburb
- Residential
- Economy mostly commercial
- Stagnant or low growth potential
- High water user
- MDC receiver

Cluster 7.

Elements: Melrose, Marlborough, Wilbraham, Holliston, Hudson, Randolph*, South Hadley, Millis, Stoughton

Representative and Descriptors:

Randolph*

- Moderate to middle-income
- Urban independent/South of Boston
- Moderately residential
- Mixed economy - highly industrial
- High growth potential
- Low water user
- Not an MDC receiver

Cluster 8.

Elements: Wakefield, Norwood, Framingham, Natick*, Leominster

Representative and Descriptors:

Natick*

- High-income area
- Urban independent/West of Boston
- Moderately residential
- Mixed economy - highly industrial
- Moderate growth potential
- High water user
- Not an MDC receiver

Cluster 9.

Elements: Canton, Avon, Bolton, Sherborn, Sudbury, Northborough*, Norfolk

Representative and Descriptors:

Northborough*

- Moderate or middle-income area
- Rural/West of Boston
- Largely residential
- Mixed economy - mostly industrial
- High growth potential
- Moderate water user
- MDC receiver

Cluster 10.

Elements: Quincy, Waltham, Braintree*, Dedham

Representative and Descriptors:

Braintree*

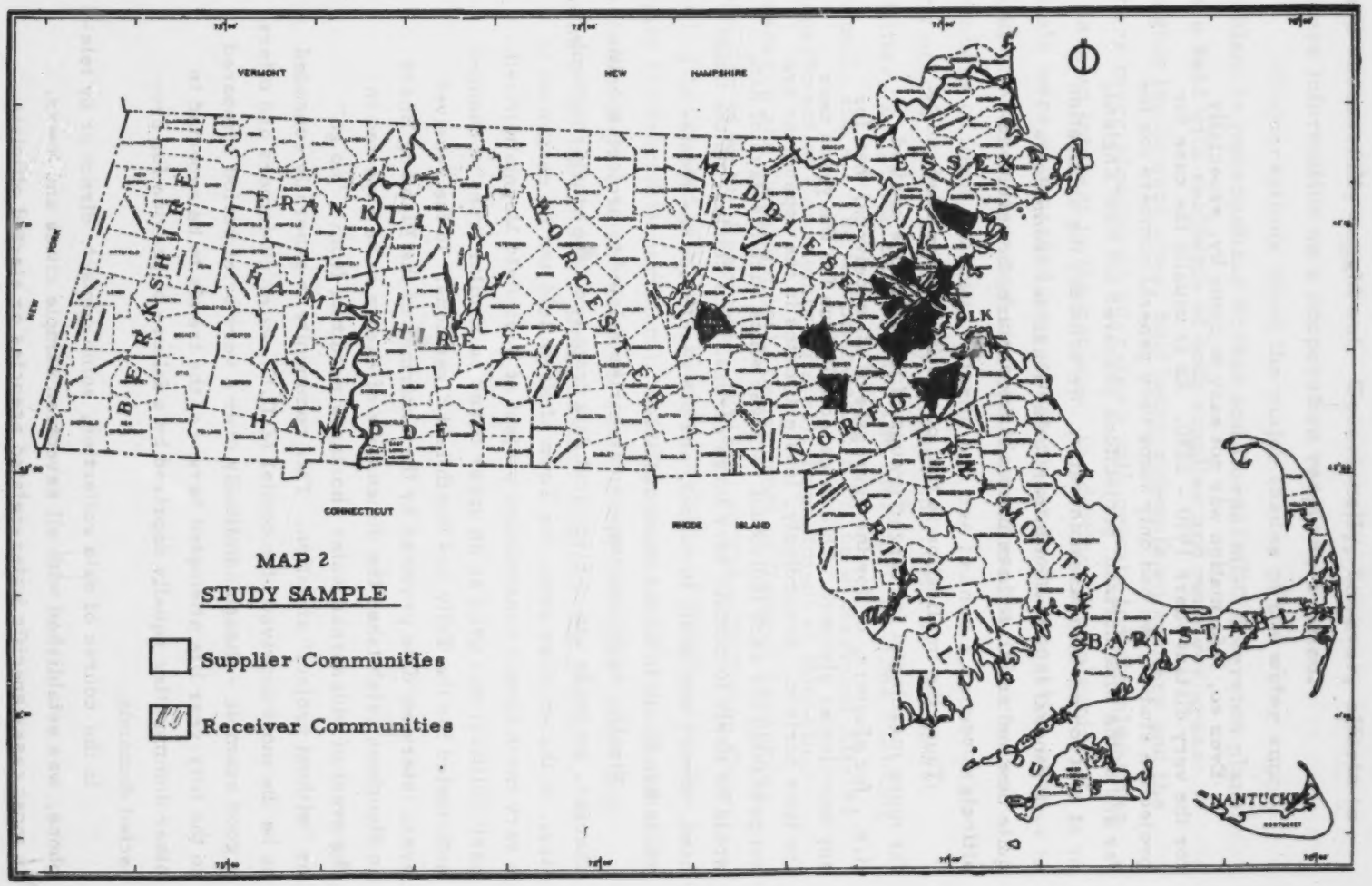
- High-income area
- Urban/South of Boston
- Moderately residential
- Industrial economy
- High growth potential
- Moderate water user
- Not an MDC receiver

Supplier communities were limited to seven: Greenfield, Erving, Royalston, Warwick, Athol, Winchendon, and Orange. As it became clear that social and economic impacts in the Connecticut Basin would be most significant for site-specific activities, remote suppliers like Deerfield and Leominster were eliminated. Though a case could be made for examining towns downstream on the Connecticut, it was felt that the environmental studies underway under separate contract would point out any important changes. From the social and economic standpoint, analysis by community outside the immediate diversion area would not have been fruitful, or even possible. Map 2 indicates communities, supplier and receiver, treated in the study.

The backbone of our analysis was the projection of economic and residential activity for the receiver area from 1970 to 2020. Of the sixty-six communities total, none but a very few had themselves done any significant forecasting. Thus, our task became extremely ambitious.

As noted above, the basic strategy was to build clusters on the basis of key economic indicators. In this way we could use information in our analysis that could not have been obtained for all sixty-six cities in a reasonable time. While most of our work actually proceeded on the 66-city level, values for certain variables were estimated for cluster sample cities only and then assumed to apply also to other communities in the same cluster. Thus, when a variable could not be feasibly collected for all receivers, we estimated it only for a representative city in each cluster and assumed that its value was shared by all other members of its cluster.[3]

[3] We indicate below which variables were, in fact, observed for all sixty-six receivers, and which variables were observed for only the ten representatives in the sample.


VERMONT
NEW HAMPSHIRE
BERKSHIRE
FRANKLIN
HAMPSHIRE
HAMPDEN
WORCESTER
MIDDLESEX
ESSEX
NORFOLK
PLYMOUTH
BRISTOL
BARNSTABLE
DUKES
NANTUCKET
CONNECTICUT
RHODE ISLAND
MAP 2
STUDY SAMPLE
Supplier Communities
Receiver Communities

Even so, information was not easy to come by, especially for the very distant years 1990 - 2020. As is usually the case for projective studies, we had only some very general numbers for the far end of the time horizon: projections prepared for New England, or at best for eastern Massachusetts. We consider the application of such general information to particular localities (sometimes quite new and small) to have been a risky venture, however sensitively done.

Thus, the implication is that our estimates are likely to be far more meaningful for larger groups of jurisdictions studied (i.e., for clusters, or for the aggregate of all receivers) than for any one cluster element. This is especially true for the years near the time horizon. Accordingly, loss estimates in the appendices are not presented for each individual receiver since such displays of data would be likely to contain very large errors. In a cluster, on the other hand, errors are likely to cancel, and the results for the cluster as a whole are likely to be far more reliable.

Finally, to fill out impact categories related to project-specific changes, we made use of historical data from two case study communities. In the supplier area, the Town of Northfield and its responses to a very much larger construction project at Northfield Mountain (Northeast Utilities) was used as an upper bound on similar types of changes anticipated for the Tully and Northfield diversions. In the receiver area, interview data provided by the Chairman of the Planning Board in Stoughton established the dimensions of change to be expected in the event of widespread water shortages resulting from a "no go" or "without project" situation. This community is generally conceded to be the most deprived of potential M. D. C. water customers and offers a good example - though admittedly over a very brief period compared to the fifty-year life attempted here - of the trends to be expected in other communities equally deprived by a failure to provide for projected demands.

In the course of data collection, some contact, direct or by telephone, was established with all seventeen sample cities and towns. In most cases specific water-related agencies or elected officials

were successfully sought out. Occasionally, however, efforts to secure information on a cooperative respondent failed.

Conversations about the major issues of the water supply problem in metropolitan Boston and Corps/MDC diversion plans were held with residents of both supplier and receiver areas: roughly ten in each area, half being sidewalk encounters and the others more structured interviews with private individuals known to have an interest in the project. In addition, five planning officials were approached as spokesmen for their respective constituencies in eastern and western Massachusetts. Four were members of local Planning Boards and one headed a county planning office. Other noteworthy sources included: 1. Northeast Utilities, 2. Maine Yankee, 3. The Metropolitan Area Planning Council, and 4. The Commonwealth's Office of Regional Affairs (Department of Community Affairs), Department of Education (Research and Development), Department of Natural Resources (Division of Water Resources, Division of Water Pollution Control), Department of Public Works, Division of Employment Security (Research Department), and Department of Public Health. Technical inputs were received exclusively from the Corps and the Metropolitan District Commission, Engineering Division.

2.0 SUMMARY

As a preamble to any statement of findings, it should be noted that our analysis and the ultimate benefit/cost framework into which it will fit have been constrained to exclude other technical solutions to the MDC water supply problem. From this fact issue two important caveats:

- Findings apply exclusively to the Tully and Northfield diversions contemplated. However, at least on the social impact side, other sources of like quantities of water (c. 120 mgd) are brought out by the arguments raised by opposition groups in the supplier area. This analysis has not considered Connecticut Basin diversions with respect to other alternatives.

- The two projects together are considered adequate to meet the demand forecast for 1990. Neither by itself will suffice, nor will both be sufficient after 1990. Thus, beyond that date, other means for augmenting safe yields must be found. However, our calculations have been carried out over a fifty-year period to be congruent with the fifty-year economic life of the project. Thus, while economic losses and related social disruptions caused by delays in implementation are likely to become intolerable long before 2020, and other solutions to the water deficit are likely to be implemented by that time, we have observed impacts over a half-century period. Loss totals for receiver communities reflect accumulated benefits foregone without certain quantities of water, whether or not the diversions under consideration were their source.

- The present data for our own calculations of water shortage - and hence dollar losses - are highly un-

certain after 1990. When carried out to 2020, projections both of population growth and water consumption, for example, are the reflection of a particular set of assumptions not universally agreed upon. Loss totals enjoying a high degree of confidence end about 1990.

The impact tables on the following pages array forecasted changes for both supplier and donor areas. It must be noted, however, that different approaches were used to develop figures for each set. In the case of suppliers, the data represent total impacts for the sum of individual towns actually affected. They should not be multiplied by a factor to obtain a sample total since there are assumed to be no appreciable impacts outside the communities listed under each impact category. Qualitative information which is keyed by superscript letter to sections of the text in 2.0, on the other hand, is generally applicable to all suppliers. The issue of the distribution of impacts is also noteworthy. For suppliers it has not been possible to go much beyond the short-term limits of construction and still deal quantitatively with impact measures. Baseline projections are simply not available after 1990, and, indeed, forecasted impacts are directly related to construction in most every case. Unfortunately, assumptions have had to fill more gaps than rigorous analysis should permit, but by working within ranges we believe gross errors to have netted out.

For the receiver area, our findings can be expressed in two different ways. First, concrete losses with and without diversion can be totalled: all receivers, normal runoff, go, total $0.00 to 1990; all receivers, normal runoff, no go, total $62,070,000 to 1990. (See Appendix Tables II, 2.1.1 and II, 1.1.1). The categories included in those totals encompass industrial, city, emergency city, revenue, commerce, sprinkling, business investment, and domestic investment losses. However, these figures say nothing of the ways in which such losses might be allocated. That is, of the $4,348,000 in revenues not collected in 1990 by all receivers under the "no go" situation, there is no way of knowing whether it would be municipal expenditures on recreation or schools that might suffer. Therefore, the loss in classrooms not built

(category 6) set at 600 rooms is merely one possible expression of total dollar loss. Similarly, housing units not built are but an alternative manifestation of losses in the private sector. Therefore, to avoid double accounting, the impacts set out in categories 5 and 6 should not be summed with those in other categories.

Still, some quantification of these two important social impacts, as well as those in categories 1, and 7-15 was necessary, if only to provide order of magnitude estimates. Therefore, data supplied by the Stoughton case study were manipulated to provide forecasts for all receivers. In every case, values were multiplied by a factor of thirty: twenty-four "no option" communities for whom prolonged water shortages could be especially severe and six others, roughly one out of every three now "partially served" or served non-members. Since the impact estimates produced in this manner are undoubtedly high, no separate account was taken of communities already fully served. That is, for example, the thirty, twenty-room schools not built because of slowed population growth in the "no go" situation represent a system maximum whether or not it is precisely the "no option" or "partially served" communities which fail to erect them.

In general, tangible impacts felt by supplier areas will be related principally to the land-taking and subsequent construction activity in three Tully project towns: Winchendon, Royalston, and Orange. Royalston is by far the most significant of the three, though only 3% of its nearly 42 square miles are even potentially exposed to alteration. Indeed, apart from the few physical structures proposed, the natural character of the area will remain unchanged. The bulk of surface work will come in remote wooded areas and along existing rights of way with what appears to be a minimum of disruption to local traffic patterns. Evidence of the tunnelling to Quabbin from Orange will be seen primarily as access shafts in two or three locations and spoil disposal sites which have not yet been finally identified.

From an economic standpoint, anticipated changes relate chiefly to the job openings stimulated by construction over a five year period.

Two qualifying points must be made, though, to establish a proper perspective on a labor influx. First, Tully and Northfield together will require something under 1,000 men -- a comparatively small number with respect to the much larger work forces assembled at Vermont Yankee in nearby Vernon and at Northeast Utilities' pumped storage facility at Northfield. Experience indicates that even if this number were to be larger than in the Vernon case, it is unlikely that the supplier area would suffer any adverse effects -- school overcrowding, housing shortages, transportation snarls, etc. Indeed, as a second mute on impacts, it may well be that many of the same workers employed in Vermont and at Northfield Mountain will move on to the Corps and M.D.C. projects as the former pair near completion. Of course, timing is a significant factor, but it is reasonable to assume that at least some transfer will be observed when construction commences.

Apart from relatively small economic impacts, social impacts related to suppliers' perceptions of equity are particularly significant. Though, objectively speaking, little real proof of harm can be demonstrated by even the most adamant opponents of implementation, supplier towns feel a kind of moral outrage at being "forced to give up our water." Irrational or not, the statements of their spokesmen belie a sense of frustration with the present system of water allocation decision-making. As perceived by the suppliers themselves, the Tully Project offers them nothing they do not already have and, more importantly, no future bargaining power.

For receivers, on the other hand, quite the reverse is true. Implementation means not only the preservation of the status quo for most communities but, for a few, the opportunity to join the M.D.C. system and "solve" their water supply troubles for good. Of course, belief that membership is a permanent answer is erroneous, but the restrictions faced in 2004 by all receivers even under the "go" scenario are preferable to the very real risks of serious shortage in the immediate future.

The lower limit of concrete losses is zero to about 2000 for the normal runoff, go, all receivers served situation. In the no go case, losses of $6,291,000 (1963 dollars) are sustained in 1982 and continue to ascend to $8,630,000 in 1990 and to a maximum of $25,297,000 in 2020. The upper bound is established in the drought, no go, all receivers served case: $14,698,000 as early as 1978 peaking in 1979 at $56,074,000. Under the normal runoff, all served, no go scenario, losses begin in 1982 and total $62,070,000 by 1990. In comparison, losses under the worst eventuality (no go, drought, all served) begin in 1978, reach $89,690,000 in 1981, are $56,799,000 during the period 1982 to 1990, for total concrete losses of $146,498,000 for the period 1978 to 1990.

Social impacts in the receiver area are principally "shadow costs" of concrete losses generated by water shortage. As municipal efforts turn to finding new sources, building bans to hold the line on new demand are a likely eventuality. Second-order effects of expenditures on water searching manifest themselves as slowed school building programs, poorer municipal services (especially fire protection.) and a general malaise in the development plans of the subject town. Moreover, it appears that citizens are likely to become discouraged and frustrated as they see their lawns dry up during watering bans. In many ways these feelings are reflected in attitudes about the desirability of their town as a place to live and work. The net result is stagnating growth, hostility toward the communities which snare the industries unable to locate in a water-deprived town, and a growing dependence on M.D.C. admission as the ultimate solution to water shortage.

Short-term, project-specific impacts on receiver areas are seen as virtually non-existent. Remembering that no actual water deliveries from the Connecticut Basin would be made short of five years from the start of construction, economic impacts perceived in the M.D.C. service area would not be water-related. For example, it might be that certain portions of the supervisory and office labor force required for construction might come from cities and towns

incidentally served by the M.D.C. Or, it is possible that equipment required for construction or permanent installation may bring revenues to a jurisdiction classified as a receiver. However, such stimuli are likely to be very small indeed because the dichotomy betwen supplier and receiver areas is nearly perfect.

Long-term impacts -- those generated by the availability of that 120 mgd increment provided by the diversions -- are more tangible. In a general sense, receiver areas will continue to develop along the optimistic lines suggested by their respective Master Plans.[1] Therefore interruption of service is not expected to occur and industry, especially, can be free of nagging doubts about the risks of water use restrictions. Developers of residential housing slated for existing M.D.C. service communities and those expected to join before 1990 are not likely to take their investments elsewhere as a result of threatened water shortages.

With respect to the water supplied itself, receiver communities benefit from implementation of the diversions in two specific ways. First, exceptionally high water quality will not change.[2] Households and industrial establishments accustomed to minimally treated upland water supplies will not be required to tolerate or compensate for waters of lower quality until such time as even the Connecticut diversions become

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[1] These documents uniformly assume unconstrained water supplies in their development of growth expectations.

[2] This is one case in which an impact, the generic name for costs and benefits, is not a change. If one were to be faithful to the semantic conventions established in this paper, the lack of change would not properly be called an impact because no deviation from expectation is involved.

inadequate to meet demand. This will be particularly important to manufacturers using large amounts of water for purposes other than cooling and those to whom deferred investments in treatment and recycling are desirable. Likewise, homeowners will not have to search for other sources of supply and sustain the cost of sprinkling losses. Moreover, it is unlikely that M. D. C. members will be subjected to the large price hikes that may be associated with the restrictions imposed earlier under a no-go condition. In fact, so little has pricing policy been based on actual water values that it is not impossible that members will demand lower rates if no restrictions are imposed.

TABLE 2

IMPACTS ON SUPPLIERS

Impact Category	Measures applied to: Greenfield Erving, Royalston Warwick, Athol Winchendon, Orange	Tully	Northfield	T + N	Neither
1. LAND USE (A) Royalston Winchendon Orange	Net change, % distribution, by use; industrial, commercial, agricultural, residential, recreational; estimated from topo sheets	<1%	0	<1%	0
	Net use change, in acres; assuming change for all land taken as an upper limit	1103	30 acres (Wendell, New Salem)	1133	0
	Net change in developable land, percent of land taken	0.1%	Negligible	0.1%	0
2. POPULATION (B)	Net change in age, race, ethnicity distribution of local populations	None	None	None	0
	Total divergence from baseline trend	0	0	0	0
3. MUNICIPAL FINANCE (C) Royalston Winchendon Orange	Loss of assessed valuation, % of total, $130,747,427 upper limit	<1 (.38%)	0	<1 (.38%)	0
	Increased assessed valuation from improved water service	N.A.	N.A.	N.A.	N.A.
	Net change (gain/loss) in tax revenue resulting from improved water service	N.A.	N.A.	N.A.	N.A.
4. COMMERCIAL ACTIVITY (D)	Net change over normal trends in gross wholesale and retail sales of those facilities affected by availability of water resource	0	0	0	0
	Number of businesses displaced by facilities	0	0	0	0
5. HOUSING (E)	Net change in number of housing units. Any relocations (est. 2-5 units) expected to be inside supplier area	None	None	None	None

N.A. = not applicable

Impact Category	Measures applied to: Greenfield Royalston Athol Erving Warwick Winchendon Orange	Tully	Northfield	T + N	Neither
6. EDUCATION (F) Greenfield Royalston	Net change in amount of classroom space required for projected change in school-age population resulting from in-migration, upper limit	1 primary classroom	1 primary classroom	2 primary classrooms	0
	Net change in cost of teacher and other staff required for projected change in school-age population resulting from in-migration; average salary @ $8,000/annum (1.5 staff per classroom)	+$8,400	+$8,400	+$16,800	0
	Net change in cost of providing school bus services because of changes in housing	U	U	U	0
	Use of facilities for educational programs, upper limit, days/year	Not likely significant			
		7	7	14	0
7. LEISURE OPPORTUNITIES (G)	Net change in total number of acres of parks and playgrounds	0	0	0	0
	Net change in extent to which planned recreation space meets American Society of Planning Officials planning standards	N.A.	N.A.	N.A.	N.A.
8. CULTURAL OPPORTUNITIES Royalston Winchendon Orange	Total number of churches, historical sites, or other cultural institutions taken	0	0	0	0
	Cost of relocation	0	0	0	0
	Increase in locational amenities, range	0-4	1	0-5	0
9. TRANSPORTATION (H)	Net change in travel time as a result of facilities construction; minutes/trip times trips/day average 20 minutes delay x 1000 trips/day, during construction	33 + hrs/day	0	33 + hrs/day	0

U = data unobtainable at this level of detail.

Impact Category	Measures applied to: Greenfield Royalston Athol Erving Warwick Winchendon Orange	Tully	Northfield	T + N	Neither
10. MUNICIPAL SERVICES Greenfield Winchendon Orange Athol	Net change in providing water, sewerage, garbage service and other municipal services	None	None	None	None
	Net change in residential insurance rates	N.A.	N.A.	N.A.	N.A.
11. SECURITY	Number of positive and negative statements about the opportunity for system failure (new facilities)	N.A.	N.A.	N.A.	N.A.
12. COMMUNITY IMAGE (I)	Changes in property values adjacent to supply facilities, per holding; totals small in view of limited takings	Average market values around pools: +10% Average market value around structures: -10%			0
	Number of positive and negative statements about communities as revealed by content analysis of local news media	10-20 aggrieved	0	10-20 aggrieved	0
13. COMMUNITY COHESIVENESS (See (I)) Royalston Winchendon Orange	Total number of community, regional, statewide and national groups taking a position for or against the project	5-10	5-10	5-10	0
14. CITIZEN INVOLVEMENT (See (I))	Total number of community, regional, statewide and national groups involved in planning of the project, times the level of their involvement, according to the following scale: 1. Attendance at hearing. 2. Citizen opportunity to critique plans at public meetings. 3. Periodic workshop planning sessions with community representatives. 4. Community advocate planner participated on equal basis with technical staff. 5. Appointment of arbitrative hearing officer (5 x 8)	15-30	0	15-30	0

Impact Category	Measures applied to: Greenfield Royalston Athol Erving Warwick Winchendon Orange	Tully	Northfield	T + N	Neither
15. INSTITUTIONAL INVOLVEMENT	Total number of jurisdictions involved in the totality of the construction process for water supply facilities	(3 towns State A. C. E.) 5	(2 towns M. D. C. State) 4	9	0
	Number of applications submitted to the M. D. C. for water supply service; disposition and frequency of refusal	N. A.	N. A.	N. A.	N. A.
16. ECONOMIC STABILITY (See Ⓓ)	Note change in local economic activity resulting from construction and related activities; 140 x $7,000 x 2 = value added in dollars	672,000	1,400,000	2,072,000	0
	New increase in private investment	0	0	0	0
17. REAL INCOME	Net change in percapita income; Net change in tax assessments per individual taxpayer Net change in regional income	No significant change anticipated			
18. EMPLOYMENT (See Ⓑ)	Number and type of construction jobs opened; substitution effects not accounted for. P: professional S: skilled U: unskilled	30P 40S 170U — 240	30P 170S 300U — 500	— 740	0
	Secondary employment (.2 - .4 times total jobs)	48	100	148	
19. INDUSTRIAL ACTIVITY	Change in number of industrial establishments	0	0	0	0
	Change in productivity indices	None	None	None	None
20. AGRICULTURAL ACTIVITY	Change in number of farm (productive) areas, upper limit	50	20	70	0
	Change in production per acre	0	0	0	0

TABLE 3
IMPACTS ON RECEIVERS

Impact Category	Measures Applied to Receiver Area (66 elements)	Tully & Northfield	Neither
1. LAND USE Ⓐ	Net change, % distribution, by use; industrial, commercial, agricultural, residential, recreational	No change	No differential change; general retardation in industrial and residential growth
	Net use change, in acres, for land taken	N.A.	N.A.
	Net change in developable land, as % of land taken	N.A.	N.A.
2. POPULATION Ⓑ	Net divergence from unconstrained baseline trend of: 2,893,100 in 1990; 4,057,800 in 2020;	2,893,100 3,689,800	2,769,600 3,384,700
	Net change in age, race, ethnicity distribution	0	0
3. MUNICIPAL FINANCE Ⓒ	Net change in revenue resulting from water service, 1990 2020	0 $10,123,000	$4,348,000 $13.898,000
	Emergency water expenditures, 1990 2020	0 $3,489,000	$1,663,000 $4,105,000
4. COMMERCIAL ACTIVITY Ⓓ	Net change (losses) over normal trends; 1990 2020	0 $1,411,000	$ 411,000 $1,713,000
	Number of businesses displaced by facilities	N.A.	N.A.
5. HOUSING Ⓔ Stoughton	Net change in number of new housing units; upper limit	0	-3750 units per year
	(Average decrease 125 units per year)		

N.A. = not applicable U = data unobtainable for calculations at this level of detail

Impact Category	Measures Applied to Receiver Area (66 elements)	Tully & Northfield	Neither
6. EDUCATION Ⓕ	Net change in amount of classroom space required for projected change in school age population; order of magnitude estimate	0	30, twenty-room schools, or 600 rooms not built
	Net change in cost of teaching staff required for projected change in school population (average salary/year = $10,000)	0	900 staff, or $9 million not spent in salaries
	Net change in cost of providing school bus services because of changes in housing	0	U
	Use of facilities for educational programs; upper limit, days/year	20	0
7. LEISURE OPPORTUNITIES	Net change in total number of acres of parks and playgrounds	0	0
	Net change in extent to which planned recreation space meets American Society of Planning Officials standards	N.A.	N.A.
8. CULTURAL OPPORTUNITIES	Total number of churches, historical sites, or other cultural institutions taken	N.A.	N.A.
	Cost of relocation	N.A.	N.A.
	Increase in locational amenities; fountains, pools, etc.	20-30	0
9. TRANSPORTATION	Net change in travel time as a result of facilities construction	N.A.	N.A.
10. MUNICIPAL SERVICES (See Ⓒ)	Net change in providing water, sewerage, garbage service or other municipal services	0	0
	Net change in residential insurance rates	0	0

Impact Category	Measures Applied to Receiver Area (66 elements)	Tully & Northfield	Neither
11. SECURITY (G)	Number of positive and negative statements about the opportunity for system failure	10-20, principally related to radiological hazards of diverting waters downstream of Vernon, Vermont Yankee outfalls	Episodic concern for prolonged and widespread water shortage caused by Quabbin depletion
12. COMMUNITY IMAGE (H)	Changes in property values adjacent to supply facilities	N.A.	N.A.
	Number of positive and negative statements about communities as revealed by content analysis of local media (average 20/year/community); order of magnitude estimate	0	c. 600 Increasing negative comment as watering restrictions put into effect
	Sprinkling losses, 1990	0	$920,000
13. COMMUNITY COHESIVENESS (H)	Total number of community, regional, statewide and national groups taking a position for or against; average of 4 per community concerned; 3 in favor 1 opposed	90 in favor 30 opposed	100 in favor
14. CITIZEN INVOLVEMENT (H)	Total number of community, regional, statewide and national groups involved in planning of the project X		
	Level of involvement on the following scale: 2 x 60 x 3 1. Attendence at hearing 2. Citizen opportunity to critique plans at public meetings	360	360

Impact Category	Measures Applied to Receiver Area (66 elements)	Tully & Northfield	Neither
14. (Cont.)	3. Periodic workshops planning sessions with community representations 4. Community advocate planner participated on equal basis with technical staff 5. Appointment of an arbitrative hearing officer		
15. INSTITUTIONAL INVOLVEMENT	Total number of jurisdictions involved in the totality of the construction process for water supply facilities;	No primary sites, connections only; upper limit, 1990 15	N. A.
	Number of applications submitted to M. D. C. for water supply service; disposition and frequency of refusal; upper limit, 1990, 23 "no option" communities 5 actual petitioners (Bedford, Burlington, Reading, North Reading, Wilmington) 2 additional communities	30, increasing frequency of admission	30, decreasing frequency of admission
16. ECONOMIC STABILITY (I)	Net change in local economic activity; value added deviation from unconstrained supply level of $ 330,400,000 in 1990 $1,035,500,000 in 2020	$270,200,000 $669,200,000	$270,200,000 $669,200,000
	Net increase in private investment	0	0
17. REAL INCOME	Net change in per capita income Net change in tax assessments per individual taxpayer Net change in regional income; Total concrete losses, 1990 Total concrete losses, 2020.	0 $20,118,000	$ 8,630,000 $25,296,000
	Total domestic investment losses, 1990 2020	0 $ 839,000	$ 522,000 $ 866,000

Impact Category	Measures Applied to Receiver Area (66 elements)	Tully & Northfield	Neither
18. EMPLOYMENT	Number and type of jobs saved/lost:	0	U Employment falls at about the same % as value added
19. INDUSTRIAL ACTIVITY	Change in number of industrial establishments Change in productivity	0	U Declines as revealed by declines in value added
	Total industrial investment losses, 1990 2020	0 $2,233,000	$ 766,000 $2,249,000
20. AGRICULTURAL ACTIVITY	Change in number of farm acres, upper limit	N.A.	N.A.
	Change in production per acre	Water used for agricultural purposes are not drawn from public supplies.	

3.0 IMPACTS ON SUPPLIER AREAS

"The very great merit of the plan now submitted is to be found in the fact that this extension of the chain of the metropolitan water supplies...will settle forever the future water policy of the district; for a comparatively inexpensive conduit can be constructed..."

Report of the State Board of Health Upon a Metropolitan Water Supply, pp. xvi-xvii, House Bill 500, February, 1895.

3.1 The "Go" Scenario

Given the substantial time which will intervene between even a prompt decision to implement the Millers and Connecticut River divisions and the actual delivery of water to Quabbin, it is possible that the relative importance of different types of impact may well change. However, with the express caveat that our findings become less certain as the time of construction advances, we have identified certain impacts -- small though they may be -- which dominate others.

Ⓐ 3.1.1 Land Use

Although approximately 1130 acres are slated for land-taking (1100 at the Tully sites, 30 at Northfield Tunnel shafts), the land use changes anticipated are minimal. Relative to the land resource base of the towns affected, takings represent about 1% of the total: in Royalston, the largest site, 895 acres compared to a total of 26,880, or 3%, would be affected; in Orange, .16%; in Winchendon, .63%. Since existing uses are almost entirely limited to undeveloped open space and since acquisition is likely to mean restricted access, the natural character of the taking area will be preserved. However, it should be pointed out that whatever unregulated hunting, fishing, or rambling presently occurs will be interrupted or may cease altogether if strict exclusion of the public is required to assure the health safety of water supply areas. In either event, the "service population" of the taking area is extremely small and significant principally in the eyes of personally affected individuals.

Apart from the recreation issue, the development potential of the host towns is not thought to be threatened. Given what the towns themselves must recognize as severe geographic disadvantages for industrial growth, it is highly improbable that the sites needed to implement the upstream diversions would ever have appreciable economic value. Their value is chiefly scenic, and since environmental integrity has been a prime engineering consideration, the landscape will not be disadvantageously affected.

Ⓑ 3.1.2 Population

Beyond the labor influx associated with construction, it is highly unlikely that current downward population trends will be reversed. In the decade between 1960 and 1970, no town in the immediate supplier area registered appreciable growth, and Winchendon, Athol and Orange experienced net outmigrations of better than 250 persons each.[1] The principal determinant of any population changes related to the diversions proposed will be the recreation issue. Should the development of recreational facilities take place, it is possible that the supplier area could see a slight increase in residential population, though probably only on a seasonal basis.

Construction-phase labor demands will have at least a temporary effect on suppliers, however. From material supplied by the M.D.C., the labor force for the Northfield Tunnel is estimated to be approximately 500 for a tunnel driving.[2] Of that number, some thirty are "wage" staff, that is, professional, supervisory and office personnel, and 300 are unskilled laborers. For the Tully Complex, the Corps projects about 170 unskilled construction workers and roughly forty skilled, to put the total field force at about 210.

To determine how the combined incomes of that work force of approximately 700 will be distributed, we can make use of the experience at the Northfield Mountain hydroelectric facility. Though the

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[1] Department of Commerce and Development, Division of Planning; Department of Community Affairs, Bureau of Planning Programs, Commonwealth of Massachusetts.

[2] The concreting portion of the project would require the same office staff plus only 160 laborers and 100 skilled craftsmen. However, if the pumped storage facility experience is any guide, it is likely that the same men will in large part account for this labor as well as tunnelling. Re-hires at Northeast Utilities took place as frequently as five and six times.

project was very much larger -- $90 million, employing a total of some 3,700 persons -- the tasks required, (such as tunneling, concreting, carpentry, iron working, pipe fitting, etc.), are of much the same nature as will be required on the diversion works, and project labor is likely to be drawn from the same sources. In a post-audit of the labor force assembled for construction of the pumped storage project,[3] Clark points out that of the 3,368 people employed in the crafts, fully 84% were hired locally; that is, only 16%, or 477 men moved into the area to obtain project work.[4] The great majority already lived within commuting distance and spent their paychecks locally. Indeed, aside from those immigrants who established temporary addresses for the term of their employ (principally hard rock miners from North Carolina, New York State, and other extraregional areas who were supporting families left behind), salaries were introduced to the economies of Central Massachusetts and southermost New Hampshire and Vermont. Thus, apart from the purchase of meals and incidentals, the salaries of both professionals and the field force were spent within the immediate region but outside the borders of the towns sharing the construction site. In fact, of the seven towns contributing more than 100 men to the

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[3] "The Labor Force Associated with the Northfield Pumped-Storage Hydroelectric Project and Its Effects on the Surrounding Communities," Frank Clark, University of Massachusetts, January, 1971.

[4] The reverse is true for supervisory personnel. Of 355 persons so employed, roughly 60% were immigrants moving to the area for the duration of the project. Most often families were settled in a population center near the project site or in trailer parks in nearby New Hampshire. In terms of spending, however, the same general patterns apply to "wage" staff as to the field force.

labor force, two (Brattleboro and Keene) are not in Massachusetts. Northfield and Erving, the site towns, are not among the seven. As for rents, the largest portion of temporary residents was set up in Greenfield or Montague, Massachusetts rooming houses, housing closer to the construction site being virtually unavailable.

Thus, if the Tully and Northfield Tunnel Projects are "union jobs", and that is the supposition, the same commutation and spending patterns are likely to apply, though at reduced levels. Table 1 shows the union locals within commuting distance of the proposed construction which are likely to provide labor, should implementation proceed.

TABLE 4

Union Locals Potentially Affected

Union	Number	City or Town	Average Commuting Time to Project Center*
Cement Masons	36	Greenfield, Mass.	35 min
International Brotherhood of Electrical Workers	161	Northampton, Mass.	50 min
United Association Local	64	Northampton, Mass.	50 min
Laborers' Local	596	Holyoke, Mass.	60 min
International Association of Bridge, Structural and Ornamental Iron Workers	357	Springfield, Mass.	1 hr, 10 min
Teamsters Local	404	Springfield, Mass.	1 hr, 10 min
International Union of Operating Engineers	98	East Longmeadow, Mass.	1 hr, 10 min
United Brotherhood of Carpenters and Joiners of America	43	Fitchburg, Mass.	60 min

*Defined as Tully, Massachusetts

Source: Adapted from Clark's "The Labor Force Associated with the Northfield Pumped-Storage Hydroelectric Project," Appendix C.

3.1.3 Municipal Finance

One other factor seems especially relevant in the determination of economic impacts on supplier areas - the issue of revenues lost to individual towns because of land absorbed into public holdings and thereby removed from the tax rolls.[5] In this particular area of the Commonwealth where tax bases in urbanized as well as rural places are not strongly diversified and thus, even comparatively minor fluctuations can mean local hardship, we made particular efforts to detect any significant decreases in collectable revenues. Unfortunately, local officials in three project towns (Orange, Royalston, and Winchendon) were either uninformed about even the general outlines of the project area, incommunicado, or able to identify only an occasional landmark in the taking area described to them. In Winchendon, the Town Clerk mentioned "several houses, no businesses, two or three tree farms, and a gun club with several acres and a clubhouse". Further probing into the actual revenues collected from property taxes on said properties proved fruitless; extensive searching for each affected ownership would be required and no town staff was available to perform it. In the case of Royalston there was no response at all to repeated inquiries. Although our investigation produced no dollar loss figures, we feel that an identification of the ownership affected and a new round of tax revenue-lost-questioning is essential. Only hard data can substitute or permanently lay to rest supplier allegations that "it is bad enough to lose our water but worse still to suffer the burden of revenues foregone".

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[5] Current estimates for Corps land-taking include 35 acres at Tarbell Brook (28 acres inundated), 1,060 acres at Priest Brook (400 inundated), 36 acres at West Branch Tully, and incidental acreage for service and vent shafts to transmission tunnels. The Northfield Tunnel requires no additional reservoir space, and takings for access shafts at Wendell and New Salem should not exceed a total of about 10-15 acres each, including spoil areas.

Once such a computation can be made, an upper limit to such losses can be established by assuming no compensation. Minimum losses, on the other hand, would occur if both the Corps and the M. D. C. were to make payments in lieu of taxes. Although that is the intention of the latter authority, it is unclear what the life of the arrangement might be: one, five, ten years, etc. In any event, the Commonwealth has in the past defrayed such losses to communities affected by flood control takings, and it is not unlikely that special pleading in the legislature will produce the same result again. However restitution is made, finally, the objective is to soften the shock of revenue drops, prevent the deterioration of existing municipal services, and avoid the retreat toward penny-wise voter attitudes which can delay or defeat much-needed school or public works investments.

For the purposes of this analysis, it has been assumed that a total decrease of $500,000 would result from plan implementation. With respect to the total assessed valuation of the three towns affected, $130,747,427, that amounts to less than a 1% drop.

Ⓓ 3.1.4 Commercial Activity

With a wide distribution of labor, salary spending should be well diffused, with no one city or town experiencing any more than marginal increases in commercial activity. In fact, whatever economic upturn might be related to construction of the diversions may well be absorbed by the "disarmament" of Northfield Mountain. These diversion projects may absorb whatever labor surplus is created by the completion of the pumped storage facility and merely maintain the employment status quo. Of course, since scheduling is uncertain, unemployment conditions at the time of construction are unknowable, and it may be that the Tully and Northfield tunnel jobs will 1) come too late to prevent an employment sag or 2) offer only substitution effects -- paying salaries obtainable elsewhere in a time of full employment. In any event, the diversion construction could well absorb the fifty-odd local hard rock miners trained at the

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hydroelectric facility.[6]

Beyond the salaries generated, short-term economic impacts also encompass the monies paid to local residents through land acquisition. Neither the magnitude nor the distribution of such payments is readily available, though a contract to investigate land acquisition requirements and alternative forms of compensation generally was let in early 1972. From the designs prepared to date for the Tully Complex, it is clear that existing public rights of way will be paralleled whenever possible, and that land takings will be held to a minimum. Again, as with salaries, benefits to the regional economy rather than to individuals are to be reckoned not just in terms of dollar totals, but by their fluidity. Clearly, several thousand dollars in a land-seller's mattress produces no multiplier effects from which generalized benefits can issue.

Long-term economic implications for suppliers center largely around the extent to which the volumes of water diverted affect industries now located in the area. As to the first issue, comments made by industry spokesmen at the public meeting held at Athol in late October indicate a concern for maintaining flows in the Millers River adequate for process purposes. From the assurances given by Corps respondents, it seems safe to conclude that no industrial enterprise will be jeopardized by flood skimming operations on Millers tributaries. In fact, at least in the purely economic sense, the marginal value of the water to be diverted is zero. As such, it must be considered "surplus" and no tangible loss to the local economy.[7]

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[6] If this were the case, even that percentage of "non-native" wages paid on the Northfield Utilities job would be introduced locally. Because spending patterns in this area are not well known, an economic study should be undertaken to specifically determine how disposable incomes in supplier areas percolate through local economies.

[7] However, we hasten to agree with Mr. Justice Holmes. A river is, indeed, "more than an amenity. It is a treasure." (N. J. v. N. Y., 283 US;336). The non-marketed value of the diverted waters is discussed below with other qualitative factors.

(E) 3.1.5 Housing

During the construction period there will be an increased demand for rental housing. It is probable that established urban centers at Greenfield, Gardner and Athol or Brattleboro and Keene and Hinsdale (trailers) will absorb whatever non-resident labor force appears and that towns nearer construction sites will not be affected. In no event is the stimulation of new housing construction foreseen. Increased demand, of course, cuts two ways. Housing prices and property values may rise for the term of construction but suffer setbacks in the general shake-out when the project is completed. Since Greenfield has been identified as an area in which the housing market is sensitive, trends there should be observed as Northfield and Vermont Yankee at Vernon wind down. Adjustments will be required for any data collected to reflect the very much smaller labor force (about 700 as compared with 3,700) anticipated for this construction job.

(F) 3.1.6 Education

From the experience of a dozen different towns surveyed by Northeast Utilities for effects on school populations,[8] only in one, Hinsdale, was overcrowding attributed to worker influxes. It should be kept in mind, however, that the nuclear generating station at Vernon, Vermont and increased business activity in Brattleboro account for much of that effect and obscure the influence of Northfield. Other school systems either had no marked increase in enrollments or cited natural growth rather than project in-migration as the cause of crowding.

As a conservative estimate of impacts felt in the supplier area sample of seven communities, we have used two primary classrooms, or about forty youngsters, for Tully and Northfield combined. Noting that Greenfield appears to be a primary response area, we have located

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[8] Bernardston, Deerfield, Erving, Gill, Greenfield, Hinsdale (N.H.), Leyden, Montague, Northfield, Orange, Warwick, Winchester (N.H.)

the demand there and calculated an average teaching staff expenditure of $8,400 for each, or around $17,000 in additional personnel.

Busing data were not available. However, because the numbers of new school-age children to be served under the "go" situation are so small and because their distribution would likely be more general than we have assumed--that is not just in Greenfield alone--any change in busing costs would be extremely small. One possible exception is in the town of Royalston where two road closings and one relocation are contemplated. Until route lines can be determined for the years in which construction would occur, however, such impacts are strictly speculative.

Ⓖ 3.1.7 Leisure Opportunities

Effects in this category are directly dependent on the extent to which present policies on public access to water supply reservoirs and tributary streams may be modified. If stringent practices as articulated by Messrs. Toole, Ahlgren, and Karalekas[9] continue, a very few resident sportsmen and occasional vacationers may be deprived of outdoor recreational opportunities now enjoyed in the upper Millers River Watershed. Their actual numbers are estimated to be under 500, however, and in no way an important part of any existing recreation-based economy. Indeed, from recent correspondence between the M.D.C., the Corps, and the Department of Public Health it appears that total isolation will not be necessary and that at least some portion of present activity may continue.

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[9] Harold J. Toole, "Recreational Use of the Boston Metropolitan Water Supply Reservoirs and Watersheds"; Clarence L. Ahlgren, "Recreational Activities on Watersheds?"; Peter C. Karalekas and J.P. Lynch, "Recreational Activities of Springfield, Mass. Water Reservoirs, Past and Present"; Journal of the New England Water Works Association, Vol. 79, No. 1, March 1965.

All this notwithstanding, the perception of local residents is that they will be "cheated" of their inalienable rights to free access.[10] The Quabbin experience has rankled in their minds for some thirty years, and references to an M.D.C. "no-man's land" are not uncommon. Their fears are of total exclusion--an eventuality as unlikely as completely unrestricted trespass.

Compromise appears to be a possible avenue to resolution. As small as the impacts would be under a no-access policy, the changes anticipated with passive and limited active recreational forms would be minimal. For example, if the English experience[11] is any guide, controlled hiking, climbing, fishing, and sailing may be permitted to members of recognized outing groups prepared to vouch for the habits of their members. Still, body contact, motor-boating, unlimited fishing and hunting, etc., though sanctioned on water supplies in the Midwest and South,[12] are not realistic possibilities in a supply system accustomed to isolation, extended detention and limited chlorination.

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[10] One must, of course, consider non-governmental limitations as well. Privately owned, posted land is as unavailable to the general public as reservations, indeed less so in many cases.

[11] Journal of the New England Water Works Association, op. cit., "Final Report of the Council on the Recreational Use of Waterworks", Institution of Water Engineers, London.

[12] Baumann points out that of the places in the Northeast and far West that allow some reservoir recreation (only 39% of the total), none in the far West and only 7% in the Northeast permit body contact. In the remainder of the United States, 50% of communities allow swimming in water supplies. From a sociological standpoint, one suspects that the strong restrictive policies of Washington and Oregon are the legacy of Yankee settlers. From a resource management standpoint, waterworks administrators in these areas occupy a minority position in the profession. See Duane Baumann, "Potential Change in the Recreational Use of Domestic Water Supply Reservoirs," in Proceedings of the Fourth American Water Resources Conference, November 1968; American Water Resources Association, Urbana, Illinois.

(H) 3.1.8 Transportation

Impacts here are almost certain to be of a temporary nature. The bulk of construction is to take place below the surface with only small dams, pumping stations and occasional access shafts at ground level. Mobility patterns in the resident population may change to some degree, but the dominantly rural nature of the area will make such disruptions infrequent.

The construction contemplated will have almost negligible effects by comparison with the recent highway work on Route 2. Heavy trucking will be required for the removal of spoil to fill areas and the delivery of equipment, but intelligent planning can avoid traffic congestion and hazards to residents. Commutation patterns for the work force will have an appreciable effect on the traffic volumes of major arteries. Locations and magnitudes can be reckoned only after the distribution of labor has been established.

(I) 3.1.9 Community Image and Cohesiveness

Objectively speaking, impacts forecasted for this category are very small. No physical separation of populations is involved apart from temporary road closings. No aesthetically undesirable structures are planned, save in the sense that any alteration of the natural scene may be thought of by some as undesirable. Yet, it is in this category that the supply areas themselves feel themselves to be most injured. Their perceptions of loss are very large, and some commentary seems appropriate.

At the outset of this impact investigation project, it was our intention to deal with cities and towns selected for the study sample on an individual basis. As our work progressed, however, we were struck by the commonalities that emerged from the data collected--particularly in supplier areas. In terms of standard socio-economic categories like population, density, employment, ethnicity, mobility, etc. and particularly in terms of attitudes, the immediate diversion environs are so

homogeneous as to be spoken of as an entity.[13] Indeed, in the sense that they share a common interest in the disposition of Millers River Basin water, they are a single community whose opposition is unanimous.

Because of the nature of the project under consideration, it is revealing to examine the source of the unanimity. The construction of Quabbin Reservoir in the late 1930's was a shock to the cultural and economic life of the area from which it has never fully recovered. As the testimony of several local people at the Orange hearing indicated, many of the residents of the towns affected by the proposed Tully Complex consider themselves refugees from the Quabbin site.

> In connection with the construction of this [Quabbin] reservoir, the corporate existence of the four towns of Enfield, Dover, Greenwich, and Prescott was terminated. Thirty-six miles of state highways were relocated, and sixteen miles of the Boston and Albany Railroad were also abolished. About 2500 persons living in 650 houses in the area were required to find new homes. A new cemetery, known as Quabbin Park Cemetery, was built in the town of Ware and 1761 bodies previously buried in thirty-four cemeteries in the area taken for reservoir purposes were removed to the new cemetery.[14]

Residents of the supplier towns feel themselves to be threatened once again. That is the root of their common cause and the most important cohesive factor in their alliance against the diversions proposed.

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13 This is not to discount the congenital sense of home rule autonomy felt by individual jurisdictions in the area. In this case, a number of otherwise competitive towns have coalesced around a single issue. Were the diversions contemplated of an intra-basin nature, one would expect much the same kind of rivalry analyzed by Kasperson in the Brockton-Silver Lake dispute. See "Political Behavior and the Decision-Making Process in the Allocation of Water Resources between Recreational and Municipal Use", Natural Resources Journal, Volume 9, April, 1969, for the history of a typical "them/us" clash over the functional allocation of Massachusetts water.

14 F.H. Kingsbury and H.J. Toole, "Water Supply of the Boston Metropolitan Area", Sanitalk, Volume 7, Number 4, August 1959.

Further, it appears to be irrelevant that the disruptive influence of the Tully and Northfield Projects is negligible by comparison with Quabbin. The social psychology operating here is transference; water for Boston means the bureaucratic machinery of the Metropolitan District Commission, the M. D. C. means wanton despoliation of all that local residents hold dear, and that means a repetition of the upheaval brought by Quabbin in the Millers Basin.[15] To point out that this connection is illogical or to argue that appropriate safeguards for local interests will be devised has been of no avail. Past experience, just as in the Brockton dispute, is all-pervasive and predispositions in the listener are ineradicable.

From the impact assessment standpoint, then, even the relatively minor changes brought by implementation of the diversions will have two principal effects: (1) demonstrate to suppliers that their impotence has not changed in thirty-odd years and (2) draw the circle of opposition even more closely together, further alienating it from the political system dominated by Eastern interests. Supplier communities will feel themselves to have been bested yet again and withdraw into a smoldering hostility.

As a consequence of this irrational behavior, a negotiating opportunity potentially instructive to all parties will have been foreclosed. Donors, for one, will be able to avoid the painful adolescence of a political coming of age; that is, their need to examine and rationalize subsets of local opinion on the relationships between their area and metropolitan Boston. From our observations, it appears that the opponents have organized themselves according to their motives:

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[15] See the transcript of testimony offered January 11, 1972 by a resident of Royalston. In her argument she specifically links the loss of her childhood home in Dana to the prospects of her own children should implementation proceed.

(1) Individual citizens who perceive the problem of water supply for the urban area as irrelevant at best, and personally threatening at worst. The issue is protection of an unconstrained life style. The response is know-nothingism. "It's Boston's problem, so let them solve it. I want to hunt and fish wherever and whenever I want."

(2) Ideologists representing academically oriented conservation interests. Spokesmen in this category care not so much for the interests of the donors specifically as for the portion of the physical environment which they inhabit. Their community is erudite, polemical, and a natural rallying point for other opponents whose credentials are less impressive. As professional warriors for the ecologic integrity of the project area, they take a parochial view which tends to obscure the political and economic questions on which the decision will ultimately turn.

(3) Civic leaders representing what they perceive as the best long-range interests of their community vis-a-vis the competition. This group includes some elected officials, businessmen, watershed association members, etc. whose homes and constituencies are within the project area. The characteristic which makes them stand out as an identifiable group is their frustration. Their formal statements as well as their conversation suggest an awareness that somewhere there is a bargain to be struck which will constructively advance their interests as well as provide Boston with a solution to a very real problem. Yet, what that mutually satisfactory compromise might be remains elusive. One fact is clear, however. If the project sponsors are to remain responsive to legitimate grievances, local people must begin to decide what the price of cooperation will be.[16]

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[16] The Tully Project differs from the Northfield Tunnel in that the latter is virtually an accomplished fact. Under the broad statutory powers of the M.D.C., construction can begin whenever the negotiations with Northeast Utilities have been concluded and the Legislature adds its endorsement. Impediments to implementation are not likely to come as a result of citizen protest. In the Tully, however, the Corps has shown itself to be responsive to local attitudes and ready to change technical plans if feasible alternatives are found.

The fact is that the appropriate institutional mechanisms for building a meaningful rural-urban linkage do not yet exist. Nor, in all justice, is it within the mission of the Corps to create them. It is the responsibility of suppliers and receivers themselves to build a healthier relationship based not on giving and getting but on sharing a common prosperity. From this point of view, not moving the water can have as much of a social cost as moving it, for in both cases the actors remain insulated and neither is rewarded for his consideration of the other.

3.2 The "No Go" Scenario

In the event that the Tully-Northfield projects are not implemented, the single most important impact in the supplier region will be at Quabbin itself. Although biological studies must evaluate the full effects of a near-complete drawdown, there is a real possibility that the ecologic viability of the reservoir would be endangered. Moreover, as the water area shrinks, the possibility of odors and exposure of the unsightly bottom areas grows. The recreational opportunities at Quabbin are, therefore, considerably diminished, not to mention the consequences for the receivers of Quabbin water which may change perceptibly in color and taste.

Less drastic are the direct economic and social impacts on suppliers. First, local stimuli caused by construction activity will be zero. Whatever buffer effect the projects might have had on the labor fallout at Vernon and Northfield will be lost. Whatever dollar gains might have been realized by local economies as a result of labor force spending and land-taking costs will be foregone. It should also be pointed out that the difference between tax revenues collected on property not taken and any payments made in lieu of taxes should implementation proceed could be counted as "savings". As noted above, however, revenue data have not been made available and it can only be assumed that the amounts involved are quite small, on the order of several thousands of dollars in the three towns directly affected.

Finally, under a "no go" situation, whatever monetary value might accrue to the "surplus" waters not diverted would be returned locally. This eventuality is highly unlikely, however, because there is no reason to foresee the development of new, water-dependent industry in the immediate donor area--at least in the 1975-1990 time frame.

Failure to build at Tully and Northfield might also deprive supplier towns of the opportunity to negotiate with the M.D.C. Insofar as the Metropolitan District Commission is the visible agent for what is an otherwise amorphous urban client, it is highly advantageous to suppliers to begin to deal with it on a fair exchange basis. This is not to say that towns can expect to sell the water diverted; their proprietary attitudes have no basis in law and so long as the riparian is satisfied according to statutory requirements, it is within the power of the Commonwealth to allocate its waters for the greatest public good. We do suggest, however, that a valuable "compensation" could be made here in the form of guarantees of M.D.C. service should the project towns someday request it.

Moreover, cooperative agreements can encompass far more than water. If, for example, seasonal population growth is consistent with the planning objectives of the area, supplier compensation might come as a cooperative agreement with an urban administration to share rural open space and recreation opportunities unavailable to its citizens. Alternatively, if new industry is desirable, formal arrangements with receiver towns containing parent companies anxious to expand could make supplier town land available on favorable terms. Or, perhaps a student exchange program between donor-receiver pairs could provide educational opportunities otherwise unavailable to both rural and urban children. Of course, the impediments to such constructive bargaining are many; fragmented agency responsibility not the least among them. But if cooperative regional development is ever to become more than wishful thinking, it is precisely such avenues of exchange that must be tried.

From the standpoint of supplier community image and cohesiveness, cancellation of diversion plans would remove the issue on which public opinion has coalesced. In a way, the oyster would be denied the irritant that makes the pearl. By having been spared "defeat", suppliers will be able to avoid the challenge of community goal-setting and return to business as usual.

4.0 IMPACTS ON RECEIVER AREAS

Receiver areas are defined as the sixty-six communities presently served by the M. D. C. or those with no option but joining in the near future. They include:

Fully Served Members

Arlington
Belmont
Boston
Brookline
Chelsea
Everett
Lexington
Lynnfield
Malden
Marblehead
Medford
Melrose
Milton
Nahant
Newton
Norwood
Quincy
Revere
Saugus
Somerville
Stoneham
Swampscott
Waltham
Watertown
Winthrop

Partly Served Members

Cambridge
Canton
Needham
Peabody
Wakefield
Weston
Winchester

Served Non-Members

Clinton
Chicopee
Framingham
Lancaster
Leominster
Marlborough
Northborough
Southborough
South Hadley
Wilbraham

Communities with No Option

Ashland
Avon
Bolton
Braintree
Dedham
Dover
Millis
Natick
Norfolk
Randolph
Sherborn
Stoughton
Holbrook
Holliston
Hudson
Lincoln
Maynard
Medfield
Stow
Sudbury
Wellesley
Westwood
Weymouth
Woburn

Before examining the methods by which economic impacts for receivers were handled, a word to distinguish them as a class from donors. First they are not homogeneous socially or economically and their planning objectives are as varied as their populations. Thus, when we speak of them as "receivers," we are taking into account only the common feature of present or anticipated inclusion in the M.D.C. service area. Second, their involvement in the dispute over Tully and Northfield is largely by proxy. As the hearings conducted by the Corps have indicated, there is no union of metropolitan citizens group, no league of town officials, no industrial organization vigorously supporting the diversions proposed. Instead, the advocacy comes from the Metropolitan District Commission, the Corps of Engineers, the Department of Public Health and other state and local agents mandated to serve the public interest in matters of safe and adequate water supply. Almost without exception, the actual consumers of the water considered for inter-basin diversion have been silent. And this public apathy is in no way atypical or surprising.[1]

4.1 Introduction

Shortages of supply are taken to mean that system yields fall short of demand. Thus a shortage does not automatically imply restrictions on water use as long as stocks are present (over 25% levels for the Quabbin Reservoir) and can be used to make up the difference between yield and demand. For further discussion of this assumption see Section 2.2. Once such stocks are exhausted, a shortage does imply a corresponding restriction on demand.

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[1] See Charles A. Ibsen, et. al., "Public Perception of Water Resource Problems," Bulletin 29, Virginia Polytechnic Institute, September 1969.

The likely responses to a shortage can be separated into the following broad categories:

(1) application of restrictions on water use, at or before the time the stocks are depleted,

(2) adjustments serving to increase supply, and

(3) adjustments serving to decrease demand.

With regard to these categories, the following assumptions were specified by Corps staff:

Assumption 1. Restrictions go into effect only when stocks are completely exhausted, and

Assumption 2. All system-wide supply adjustments are ruled out within the time horizon of the study (1976-2026) except for those represented by the Tully and Northfield Projects.

Our analysis is therefore limited to the last class of adjustments: the way in which demand actually comes to equal supply. It is important to stress here the counter-factual nature of Assumption 2; under the "no go" scenario (i.e. in the absence of the Tully and Northfield Projects), all of the burden of adjustment is shifted onto demand, and supply increases are viewed as permanently impossible. Actors in the system are therefore seen as ignoring (or being forced to ignore) the most natural course of action under the circumstances: the search for new sources of water. In any case, given the assumption, two types of demand adjustments are likely to take place:

(1) decreases in the number (or size) of water users in the system relative to projections which do not consider water as a binding constraint. These "deviations" take place because (a) some existing users leave the system, (b) some users who would normally have moved into the system fail to do so, and (c) the number (or size) of existing users does not expand as rapidly as it would have had water not entered as a binding constraint.

(2) users who are in the system (i.e. stay in, or enter the area despite restrictions) restrict their use of water (through investments in recirculation, more discriminating use, etc.).

Thus we view the adjustment in an interactive sense; permanent shortages imply a reduction in water use in the system (and therefore lower the shortage); an equilibrium is reached where all remaining water users are willing to stay in the system at the level of shortage that obtains as a result of their presence. These remaining users then make adjustments of the second type to bring actual demand in line with supply.

To examine these interactions, we have built a computer simulation model. With the aid of the model, we examined the following situations for the time period 1970-2020:

I. Supply is always adequate, and meets projected demand ("Unconstrained State")

II. Supply includes the Tully and Northfield additions ("Go")
- II.a Under normal run-off condtions
  - II.a.1 All potential receivers are served
  - II.a.2 No new communities are added to MDC service
- II.b Under drought conditions
  - II.b.1 All potential receivers are served
  - II.b.2 No new communities are added to MDC service

III. Supply maintained at present levels ("No Go")
- III.a Under normal run-off conditions
  - III.a.1 All potential receivers are served
  - III.a.2 No new communities are added to MDC service
- III.b Under drought conditions
  - III.b.1 All potential receivers are served
  - III.b.2 No new communities are added to MDC service

Our simulations provide two types of loss estimates that correspond to the adjustment types (visualized as "leaving" vs. "suffering") considered above. The first type of loss estimate involves the deviation between realized population and economic activity and unconstrained (i.e. "enough supply") population and economic activity. The second type of loss estimates we call "concrete losses" for these involve dollar estimates of what the restrictions cost water users who were in fact present at the time of the shortage.

We stress that only permanent shortages were assumed to lead to deviations between realized and unconstrained demand. For alternatives examining the effects of a drought, the realized demand was assumed to be unaffected by temporary shortages caused by the drought itself. Thus, while the realized demand is smaller for the "no go" alternative than for the "go" alternative, the realized demand is the same under "no go, with drought" as under "no go, normal".

A word of caution: it makes absolutely no sense to numerically add the two types of losses, even though some deviations for various kinds of economic activities are stated in dollar terms. More will be said later about what part of these deviations could, in fact, be counted as losses. Suffice it to say here that even from the narrowest accounting viewpoint, the magnitude of the deviations vastly overstates the actual losses incurred.

4.2 System Adequacy Through Time

4.2.1 In this section we begin to fill out the framework presented above by describing the methodology and results of the computations that led to values for system supply, demand, and restriction levels.

4.2.2 System Supply: Stocks

The Corps has estimated that in 1971 the Quabbin and Wachusett Reservoirs were at 50% joint capacity, amounting to about 239Bb of water. About half of this amount (119Bb) was considered available for consumption without adversely affecting the quality of water in the reservoirs, or their ability to ride out short-term fluctuations in demand or inflow. This assumes that the 25% [2] annual average level still provides adequate intra-year buffering capacity, that is, as long as 25% average levels are maintained, typical intra-year variations in inflow and outflow will at no time call for reservoir levels below what is actually needed to maintain quality. Thus the system's initial stock was set at 119Bb, or equivalently at 328

[2] The 25% figure was provided by the Corps.

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mgd-years.[3] By 1976, this stock will have fallen to 268 mgd-years. Depending on whether or not the Tully and Northfield Projects are adopted, these stocks will either increase or decrease after 1976, as indicated below in Tables 7a-h.

System Supply: Yields

The amount of yield available depends on (a) whether or not the Tully and Northfield Projects are implemented, and (b) what run-off conditions exist during the study period. We hypothesized two run-off conditions: "normal" and "drought," based on data supplied by the Corps.

The "normal" situation assumes 300 mgd yields from the present "no go" sources, and 420 mgd under the "go" scenario. In the "drought" situation we assumed that the Tully-Northfield part of the system (120 mgd) would not experience lower yields, but that the present sources would.[4] The drought itself was designed to replicate run-off conditions during 1962-1966, and was assumed to take place between 1976 and 1980. Table 5 summarizes the system yields under these alternative situations.

4.2.3 System Demand: "Enough Supply"

We first computed system demands as projected on the basis of growth unconstrained by water availability. In order to do so, we had to develop water demand equations for each potential receiver

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[3] For ease of comparability with yields and demands, we shall speak of stocks in terms of mgd-years; the conversion simply involves division by .365.

[4] See Section 8.4 for revised assumption and its effect.

Table 5. System Yields under Varied Conditions (mgd)

	Normal		Drought		Drought*
	No Go	Go	No Go	Go	Revised Go
Before 1976	300	300	300	300	300
1976	300	420	228	348	332
1977	300	420	220	340	308
1978	300	420	185	305	288
1979	300	420	83	203	114
1980	300	420	136	256	226
After 1980	300	420	300	420	420

* See Section 4.7.4 for explanations

community.[5] The unconstrained demand estimates are presented in Table 6. The two columns indicate the size of demand given different assumptions about new membership in the M. C. D. system. The differences between these estimates and the Corps' estimates, slight as they are, will be discussed later.

4.2.4 Realized Potential Demand

As argued earlier, restrictions cannot be computed directly from the unconstrained demand situation because (1) some water-users will have left the system in face of a permanent shortage, and (2) still others would not have entered the system, or failed to expand their activities. Consequently it is necessary to introduce an equation which explains how far below the unconstrained trend the demand will fall--given the level of existing restrictions. The actual equation chosen is fully described in Section 4.3.1.

We introduce the model here as follows: Let D^* be unconstrained demand, D^R realized demand, and R(r) the ratio of realized to unconstrained demand. The fraction R(r) is assumed to depend on r, the restriction rate, and it takes on values between 0.0 and 1.0.

(2.1) $$D^R = R(r)D^*$$

But the restriction rate itself depends on realized demand D :

(2.2) $$r = \frac{D^R - \text{Supply}}{D^R}$$

Schematically, we used an iteration process illustrated in Figure 1.

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[5] This is discussed in detail in Section 4.5.1. We simply add here that for the period 1971-1990, total system demand estimates were made available to us by the Corps, and our demand equations were required to approximate these estimates.

Table 6. Unconstrained System Demand (mgd)

	All Receivers	Present Served Only
1970	300	300
1976	331	320
1977	336	323
1978	341	326
1979	346	329
1980	351	333
1981	359	339
1982	367	345
1983	375	352
1984	383	358
1985	391	365
1986	400	371
1987	408	378
1988	416	384
1989	424	390
1990	432	397
2000	508	451
2010	605	515
2020	725	590

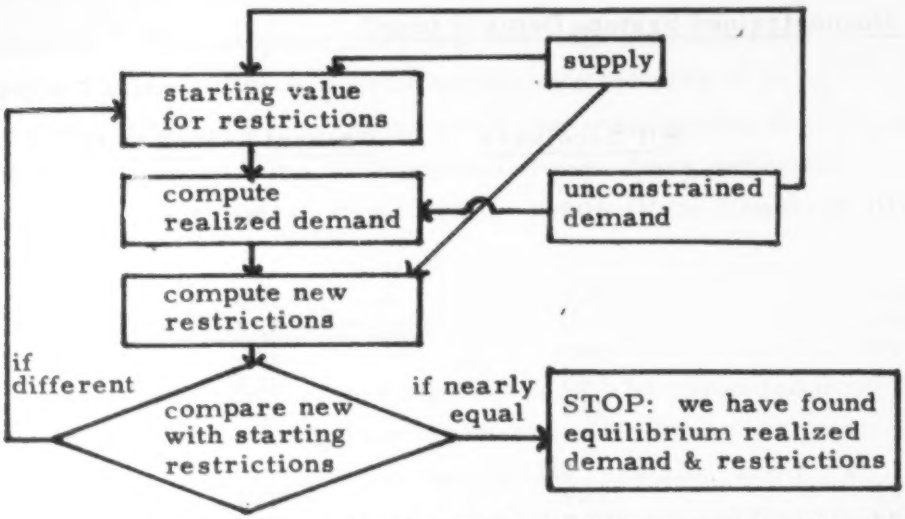

Figure 1. Iterative Determination of Restrictions and Realized Demand

The equilibrium realized demands are very close to the unconstrained demands at low restriction levels, and begin to diverge significantly only at restriction rates of 30-40%.

We must add here that the iteration process outlined above was quite complex (as it will become clear in Section 4.6). We dealt with each receiver community separately, since a community may experience internal restrictions significantly different from those of the whole MDC system depending on its local sources of supply. The overall results are contained in Tables 7a-h.

4.2.5 Restrictions on Realized Demand

In the previous section (2.4), we did not specify the actual value of the "supply" variable. It was computed over time as follows:

(2.3) $$\text{Supply}_t = \text{Stock Available}_t + \text{Yield}_t$$

The amount withdrawn from stocks in turn depended on restricted, realized demand:

(2.4) $$\text{Withdrawals}_t = (1 - r_t)D_t^R - \text{Yield}_t$$

and stocks changed over time according to:

(2.5) $$\text{Stock Available}_t = \text{Stock Available}_{t-1} - \text{Withdrawals}_{t-1}$$

Negative withdrawals (additions to stock) were permitted, and took place for a period under the "go" alternative. These data are also shown in Tables 7a-h. The maximum capacity of the Quabbin-Wachusett system of 1312 mgd-years was not achieved even under the "go" scenario. The accumulative nature of the "go" scenario nevertheless acts as an important distinguishing characteristic; a good deal of the difference between the "go" and "no go" cases (under this extremely long-horizonted analysis) comes from the way the "go" system is able to provide large stocks for post-1990 years. Table 7 presents a summary of approximate dates when the Quabbin reaches the 25%, in our terminology zero-stock, level.

The status of the system under various scenarios is examined more closely in Tables 7a-h. They also list the restriction rates which had to be applied after stocks ran out, and after the demand adjustments of Section 4.2.4 had taken place.

Table 7. Year of Stock-Exhaustion

Year	Scenario
1978	No-Go, All Served, Drought No-Go, Present Served, Drought
1982	No-Go, All Served
1984	No-Go, Present Served
1996	Go, All Served, Drought
2004	Go, All Served
2009	Go, Present Served, Drought
2014	Go, Present Served

Table 7.a

SYSTEM STATUS

No Go (1) or Go (2): 1

All (1) or Present Served Only (2): 1

Year	Demand	Restriction	Withdrawal	Stock
1970	299.9	0.0	0.0	328.0
1976	330.5	0.0	30.5	237.5
1977	335.6	0.0	35.6	201.8
1978	340.7	0.0	40.7	161.1
1979	345.8	0.0	45.8	115.2
1980	350.9	0.0	50.9	64.3
1981	359.0	0.0	59.0	5.2
1982	358.7	0.149	5.2	0.0
1983	364.1	0.176	0.0	0.0
1984	368.9	0.187	0.0	0.0
1985	373.4	0.197	0.0	0.0
1986	381.0	0.213	0.0	0.0
1987	384.9	0.221	0.0	0.0
1988	392.2	0.235	0.0	0.0
1989	395.6	0.242	0.0	0.0
1990	402.7	0.255	0.0	0.0
2000	448.3	0.331	0.0	0.0
2010	494.0	0.393	0.0	0.0
2020	548.9	0.453	0.0	0.0

Table 7b

SYSTEM STATUS, DROUGHT

No Go (1) or Go (2): 1
All (1) or Present Served Only (2): 1

Year	Demand	Restriction	Withdrawal	Stock
1970	299.9	0.0	0.0	328.0
1976	330.5	0.0	102.5	165.5
1977	335.6	0.0	115.6	49.8
1978	340.7	0.311	49.8	0.0
1979	345.8	0.760	0.0	0.0
1980	350.9	0.612	0.0	0.0
1981	359.0	0.164	0.0	0.0
1982	358.7	0.164	0.0	0.0
1983	364.1	0.176	0.0	0.0
1984	368.9	0.187	0.0	0.0
1985	373.4	0.197	0.0	0.0
1986	381.0	0.213	0.0	0.0
1987	384.9	0.221	0.0	0.0
1988	392.2	0.235	0.0	0.0
1989	395.6	0.242	0.0	0.0
1990	402.7	0.255	0.0	0.0
2000	448.3	0.331	0.0	0.0
2010	494.0	0.393	0.0	0.0
2020	548.9	0.453	0.0	0.0

Table 7c

SYSTEM STATUS

No Go (1) or Go (2): 1
All (1) or Present Served Only (2): 2

Year	Demand	Restriction	Withdrawal	Stock
1970	299.9	0.0	0.0	328.0
1976	319.5	0.0	19.5	248.5
1977	322.7	0.0	22.7	225.8
1978	326.0	0.0	26.0	199.8
1979	329.2	0.0	29.2	170.6
1980	332.5	0.0	32.5	138.1
1981	338.9	0.0	38.9	99.2
1982	345.3	0.0	45.3	53.9
1983	351.8	0.0	51.8	2.1
1984	350.0	0.137	2.1	0.0
1985	356.1	0.158	0.0	0.0
1986	360.0	0.167	0.0	0.0
1987	365.9	0.180	0.0	0.0
1988	369.2	0.187	0.0	0.0
1989	372.0	0.193	0.0	0.0
1990	377.9	0.206	0.0	0.0
2000	415.4	0.278	0.0	0.0
2010	453.0	0.338	0.0	0.0
2020	488.6	0.386	0.0	0.0

Table 7d

SYSTEM STATUS, DROUGHT

No Go (1) or Go (2): 1
All (1) or Present Served Only (2): 2

Year	Demand	Restriction	Withdrawal	Stock
1970	299.9	0.0	0.0	328.0
1976	319.5	0.0	91.5	176.5
1977	322.7	0.0	102.7	73.8
1978	326.0	0.206	73.8	0.0
1979	329.2	0.748	0.0	0.0
1980	332.5	0.591	0.0	0.0
1981	338.9	0.115	0.0	0.0
1982	345.3	0.131	0.0	0.0
1983	351.8	0.147	0.0	0.0
1984	350.0	0.143	0.0	0.0
1985	356.1	0.158	0.0	0.0
1986	360.0	0.167	0.0	0.0
1987	365.9	0.180	0.0	0.0
1988	369.2	0.187	0.0	0.0
1989	372.0	0.193	0.0	0.0
1990	377.9	0.206	0.0	0.0
2000	415.4	0.278	0.0	0.0
2010	453.0	0.338	0.0	0.0
2020	488.6	0.386	0.0	0.0

Table 7e

SYSTEM STATUS

No Go (1) or Go (2): 2
All (1) or Present Served Only (2): 1

Year	Demand	Restriction	Withdrawal	Stock
1970	299.9	0.0	0.0	328.0
1976	330.5	0.0	-89.5	357.5
1977	335.6	0.0	-84.4	441.8
1978	340.7	0.0	-79.3	521.1
1979	345.8	0.0	-74.2	595.2
1980	350.9	0.0	-69.1	664.3
1981	359.0	0.0	-61.0	725.2
1982	367.1	0.0	-52.9	778.1
1983	375.3	0.0	-44.7	822.8
1984	383.4	0.0	-36.6	859.5
1985	391.5	0.0	-28.5	888.0
1986	399.6	0.0	-20.4	908.5
1987	407.7	0.0	-12.3	920.8
1988	415.8	0.0	-4.2	925.1
1989	423.9	0.0	3.9	921.2
1990	432.0	0.0	12.0	909.2
2000	508.0	0.0	88.0	371.0
2010	563.7	0.255	0.0	0.0
2020	627.9	0.331	0.0	0.0

Table 7f

SYSTEM STATUS, DROUGHT

No Go (1) or Go (2): 2
All (1) or Present Served Only (2): 1

Year	Demand	Restriction	Withdrawal	Stock
1970	299.9	0.0	0.0	328.0
1976	330.5	0.0	-17.5	285.5
1977	335.6	0.0	-4.4	289.8
1978	340.7	0.0	35.7	254.1
1979	345.8	0.0	142.8	111.2
1980	350.9	0.0	94.9	16.3
1981	359.0	0.0	-61.0	77.2
1982	367.1	0.0	-52.9	130.1
1983	375.3	0.0	-44.7	174.8
1984	383.4	0.0	-36.6	211.5
1985	391.5	0.0	-28.5	240.0
1986	399.6	0.0	-20.4	260.4
1987	407.7	0.0	-12.3	272.7
1988	415.8	0.0	-4.2	276.9
1989	423.9	0.0	3.9	273.0
1990	432.0	0.0	12.0	261.0
2000	496.4	0.154	0.0	0.0
2010	563.7	0.255	0.0	0.0
2020	627.9	0.331	0.0	0.0

Table 7g

SYSTEM STATUS

No Go (1) or Go (2): 2
All (1) or Present Served Only (2): 2

Year	Demand	Restriction	Withdrawal	Stock
1970	299.9	0.0	0.0	328.0
1976	319.5	0.0	-100.5	368.5
1977	322.7	0.0	-97.3	465.8
1978	326.0	0.0	-94.0	559.8
1979	329.2	0.0	-90.8	650.6
1980	332.5	0.0	-87.5	738.1
1981	338.9	0.0	-81.1	819.2
1982	345.3	0.0	-74.7	893.9
1983	351.8	0.0	-68.2	962.1
1984	358.2	0.0	-61.8	1023.9
1985	364.6	0.0	-55.4	1079.3
1986	371.1	0.0	-48.9	1128.2
1987	377.5	0.0	-42.5	1170.7
1988	383.9	0.0	-36.1	1206.8
1989	390.3	0.0	-29.7	1236.5
1990	396.8	0.0	-23.2	1259.7
2000	451.0	0.0	31.0	1198.0
2010	515.0	0.0	95.0	545.0
2020	549.9	0.236	0.0	0.0

Table 7b

SYSTEM STATUS, DROUGHT

No Go (1) or Go (2): 2
All (1) or Present Served Only (2): 2

Year	Demand	Restriction	Withdrawal	Stock
1970	299.9	0.0	0.0	328.0
1976	319.5	0.0	-28.5	296.5
1977	322.7	0.0	-17.3	313.8
1978	326.0	0.0	21.0	292.8
1979	329.2	0.0	126.2	166.6
1980	332.5	0.0	76.5	90.1
1981	338.9	0.0	-81.1	171.2
1982	345.3	0.0	-74.7	245.9
1983	351.8	0.0	-68.2	314.1
1984	358.2	0.0	-61.8	375.9
1985	364.6	0.0	-55.4	431.4
1986	371.1	0.0	-48.9	480.2
1987	377.5	0.0	-42.5	522.7
1988	383.9	0.0	-36.1	558.8
1989	390.3	0.0	-29.7	588.5
1990	396.8	0.0	-23.2	611.7
2000	451.0	0.0	31.0	550.0
2010	500.0	0.160	0.0	0.0
2020	549.9	0.236	0.0	0.0

4.3 Loss Incurred: A Catalog

In Section 4.2 we described the characteristics of the MDC system under various alternative conditions considered in context of our study. Here we turn to the loss implications of the system's inadequacy. The unconstrained activity projections which form a base for these losses are fully described in Section 4.4.

4.3.1 Deviations from Unconstrained Trend

As argued throughout earlier sections, it is highly improbable that various types of activities will realize their normally projected trends if serious and permanent water shortages develop in the MDC system.

We distinguish now between four different activities, likely to have quite different responses to the existence of water shortage:

(1) Manufacturing activities which involve relatively heavy water usage

(2) Other manufacturing activities

(3) Non-manufacturing economic activities

(4) Residential activity, or population in the community

We have projected these four activities on the basis of their likely unconstrained growth in each of the 66 receiver communities. (See Section 4.4.) Now the question: by how much will these realized activities diverge from their unconstrained level given water use restrictions?

We must admit, first of all, that the question is not likely to have a concrete answer because too many variables not involved in our analysis play major roles in determining the size of the divergence.

In theory at least, we might be able to determine the point at which it is no longer profitable for a given actor to locate in the system by carefully comparing the costs of suffering from restrictions with the costs of locating outside the system. This is illustrated in Figure 2.

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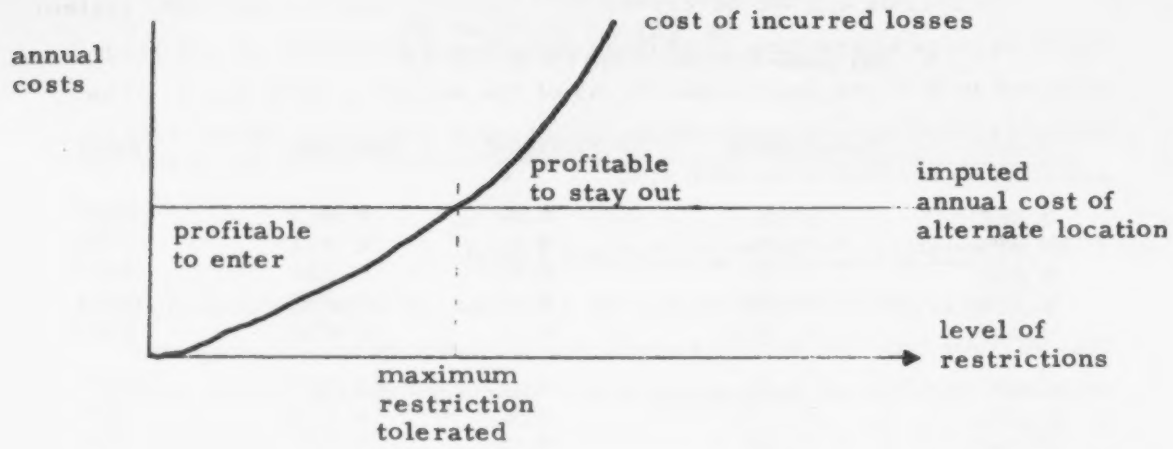
Figure 2. Decision to Enter the System



In practice, however, we do not have nearly enough information to guide us. The information needed to specify relocation costs is large even for industry, and is likely to depend on the particular activity, community, and time that we are examining. What makes the picture even more complicated is that not only do the above characteristics of a particular industry enter into the cost of relocation, but also the characteristics of the entire national or even international environment. Thus restrictions on water use in the "second best" location (whether inside or outside the MDC area) make a major difference, along with questions such as the cost of finding adequate labor, raw materials, and transportation facilities elsewhere.

In short, there is no way of isolating the effect of water availability from countless other determinants of industrial location. Location economics has little enough to offer in terms of general, quantifiable determinants of industrial location, and in particular, has not dealt with water availability in any level of detail. Moreover, we do not know of any studies where a similarly serious shortage occurred and was not foreseen in projections, and doubt very much that such studies could ever be meaningful. And if it is difficult to determine the effect of shortages on economic activity, it is even less possible to guess their effects on residential activity, or the size of the population in a community.

The costs of relocation must now include no-dollar-value social costs of leaving homes, friends, and jobs, in addition to the quantifiable elements of moving costs.

Surely, water availability had a great deal to do with why Dry Well, Texas developed into Dry Well, Texas as opposed to Boston, Massachusetts. But after many decades of development, other constraints have come to play a far more important role, and now their effects are inseparable. Dry Well could not turn into Boston even if a new, infinitely large water source were discovered next door, and Boston can become a ghost town only under the least realistic assumption--a sharp, unyielding constraint on its water supply despite the obvious existence of additional sources. Unfortunately, that is exactly the thrust of Assumption 2 (p. 1).

The way out of this dilemma involves making guesses--and they should be acknowledged as such--by assuming some response pattern related to the size of restrictions. Our model is set up to include any such guess at the response function; however, within the limits of research time available, we explored only one such function (plotted in Figures 3 and 4). The data behind these curves are reported in more detail in Table 8.

We feel these curves to be reasonable, but as the foregoing indicates, there is no concrete basis on which their "reasonableness" can be tested. Sensitivity analysis might have given us more confidence in the function, but project time pressures made it impossible.

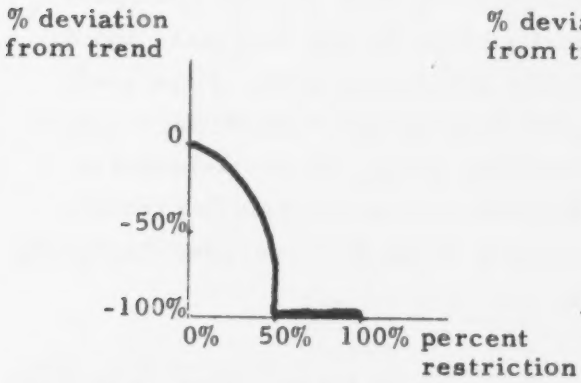


Figure 3. Water-Using Manufacturing Response

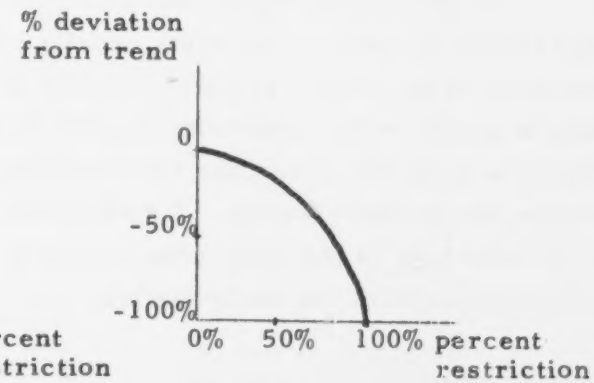


Figure 4. Other Manufacturing, Non-Manufacturing, Population Response

4.3.2. Concrete Losses by Community

Our tools are far better for evaluating the losses incurred by activities that do in fact remain in or enter the MDC area, and our results here are considerably more reliable than the computations which provided the base-line itself, i.e. the realized activity levels as described in Section 4.3.1.

General Methodology

In measuring economic impacts produced by water shortage, we have a choice of two approaches. The first involves a systematic categorization of the losses that may result and their conversion into meaningful measures (for example dollars) on the basis of economic theory or expert judgment. The second approach involves the estimation of losses on the basis of evidence gathered in the analysis of an actual experience similar to the situation under study. Each of these approaches has its advantages. In the first case, we are reasonably sure that the losses under study are, in fact, the kind that the community is likely to experience, but we are much less certain about the magnitude of such losses. In the second case, we are well informed about how large the losses actually were, but face difficulties in relating the losses to the community we are studying; the "data community" --the one which experienced losses--may have had a different enough composition (in terms of industry, population, housing, etc.) to make the task of relating its losses to the potential losses of the "study community" quite difficult.

Nevertheless, when the option of using data derived from past experience is open, economists usually prefer to use that data, and do whatever is necessary to adapt it to the problem at hand. Since such data is available for communities not unlike those in the Millers sample and for a situation much like the one under study, we have elected to pursue the second strategy. To estimate the losses resulting from a water shortage in the MDC area, we look to the data recorded during the natural drought of the early Sixties.

Table 4. REALIZED VS POTENTIAL ACTIVITY

SHORTAGE	POP	WATER-W	OTHER-W	COMMERCE
0.0	1.000	1.000	1.000	1.000
0.02	1.000	0.998	1.000	1.000
0.04	0.998	0.994	0.998	0.998
0.06	0.996	0.986	0.996	0.996
0.08	0.994	0.974	0.994	0.994
0.10	0.990	0.960	0.990	0.990
0.12	0.986	0.942	0.986	0.986
0.14	0.980	0.922	0.980	0.980
0.16	0.974	0.898	0.974	0.974
0.18	0.968	0.870	0.968	0.968
0.20	0.960	0.840	0.960	0.960
0.22	0.952	0.806	0.952	0.952
0.24	0.942	0.770	0.942	0.942
0.26	0.932	0.730	0.932	0.932
0.28	0.922	0.686	0.922	0.922
0.30	0.910	0.640	0.910	0.910
0.32	0.898	0.590	0.898	0.898
0.34	0.884	0.538	0.884	0.884
0.36	0.870	0.482	0.870	0.870
0.38	0.856	0.422	0.856	0.856
0.40	0.840	0.360	0.840	0.840
0.42	0.824	0.294	0.824	0.824
0.44	0.806	0.226	0.806	0.806
0.46	0.788	0.154	0.788	0.788
0.48	0.770	0.078	0.770	0.770
0.50	0.750	0.000	0.750	0.750
0.52	0.730	0.0	0.730	0.730
0.54	0.709	0.0	0.708	0.708
0.56	0.686	0.0	0.686	0.686
0.58	0.664	0.0	0.664	0.664
0.60	0.640	0.0	0.640	0.640
0.62	0.616	0.0	0.616	0.616
0.64	0.590	0.0	0.590	0.590
0.66	0.564	0.0	0.564	0.564
0.68	0.538	0.0	0.538	0.538
0.70	0.510	0.0	0.510	0.510
0.72	0.482	0.0	0.482	0.482
0.74	0.452	0.0	0.452	0.452
0.76	0.422	0.0	0.422	0.422
0.78	0.392	0.0	0.392	0.392
0.80	0.360	0.0	0.360	0.360
0.82	0.328	0.0	0.328	0.328
0.84	0.294	0.0	0.294	0.294
0.86	0.260	0.0	0.260	0.260
0.88	0.226	0.0	0.226	0.226
0.90	0.190	0.0	0.190	0.190
0.92	0.154	0.0	0.154	0.154
0.94	0.116	0.0	0.116	0.116
0.96	0.078	0.0	0.078	0.078
0.98	0.040	0.0	0.040	0.040

The sections below assess:

(1) the data that is available, and the methodology used to assemble it, and

(2) the problems of adapting this information to other communities.

The Data Base

The information which we relate to the communities under study is the result of an analysis of the consequences of the 1962-1966 drought in selected Massachusetts cities: Drought and Water Supply by C. S. Russell, D. G. Arey, and R. W. Kates, for Resources for the Future (RFF).

The RFF study dealt with 48 Massachusetts communities chosen out of 156 for intensive interview surveys which concentrated on the characteristics of the municipal water supply system. From these 48 communities, three were chosen for detailed investigation of drought losses: Braintree, Fitchburg, and Pittsfield which experienced annual water shortages of 9.7%, 22%, and 14%, respectively, during the 1962-1966 period. Most of the loss estimates for the period are based on a detailed interview survey of various segments of these communities. The definitions and assumptions used to arrive at values for dollar losses in these communities are presented below.

A. Sectors: Four major sectors of the communities' economy can be differentiated: industrial, commercial, municipal, and domestic. A fifth "sector" is composed of various miscellaneous impacts which cannot be conveniently accommodated in any of the above economic sectors. It is important, of course, to prevent double accounting, that is, to make sure that losses are counted only in one sector. For example, the M.D.C. and the local water departments lose considerable revenue from not being able to sell the water that is unavailable. Since this loss is charged to the M.D.C. and the local municipal sectors, the cost of the water not available to the other sectors cannot be charged as a loss to those sectors as well. Their losses should include only the damages in excess of what it would have cost them to purchase the desired amount of water. A number of appropriate adjustments were undertaken in the RFF study to circumvent such difficulties.

B. Loss Categories: Departing somewhat from the RFF typology, we shall distinguish two major types of losses: those experienced annually as a consequence of shortage, and those losses which are experienced once and for all given a certain shortage level. In the latter category belong all losses connected with investment projects undertaken to either permanently increase the supply of the water available to a sector, or to permanently decrease the consumption rate of the sector. Once such investment projects are undertaken, the losses that may result will not be experienced again unless the shortage grows more severe. Altogether seven types of concrete losses were analyzed in this study.

LOSS TYPE 1. Annual Loss Categories: Industrial Sector. Two major subheadings fall in this category:

(1) Business losses resulting from forced slowdowns or shutdowns in production due to drought, and

(2) Disparate costs like dry-hole wells, cloud-seeding, and water conservation programs. The magnitude of these losses was estimated first as lost value added for shutdowns and forced slowdowns, and then as the costs of the various "other" projects.

LOSS TYPE 2. Annual Loss Categories: Municipal Sector. The subheadings distinguished here include:

(1) Lost Revenue on water not sold (the prevailing price of water times the shortage computed as the difference between potential demand and available supply),

(2) Emergency Supply Costs, based on interviews with water system managers and press accounts,

(3) Other, the "costs of redistributing the town's available water in a desired pattern as in hiring spray trucks to cart river water to thirsty trees and shrubs", and certain investment projects which ought to be classified as Permanent Losses: for example, the costs of "a well for a town swimming pool ...efforts to find new groundwater sources, etc.". For our

purposes, the Municipal Other category is treated as an annual cost because it has been impossible to split apart this category into its appropriate investment and annual components.

(4) Tree Losses classified under the Miscellaneous category in the RFF study were included here; these losses reflect the town's inability to water trees as a result of shortage.

LOSS TYPE 3. Annual Loss Categories: Revenues Lost to Municipal Sector. Included here were the losses of municipal revenue on water that the town was not able to sell because of the restrictions. Our data for this loss type were not based on the RFF study; we estimated markup margins on water purchased from the MDC on the basis of a telephone survey of the sample towns' water departments. Not included here are the revenues lost by the MDC system itself; this category includes only the markup lost by the client municipalities. More is said about these estimates below in Relating Losses to Other Communities.

LOSS TYPE 4. Annual Loss Categories: Commercial Sector. As in the industrial sector, losses include:

(1) Business Losses, and

(2) Projects aimed at reducing consumption. This sector consists of non-manufacturing establishments, including firms engaged in trade and services.

LOSS TYPE 5. Annual Loss Categories: Domestic Sector. The only subheading falling in this category consists of "Sprinkling Losses, the losses of consumer surplus resulting from a complete or partial ban on lawn sprinkling". This was estimated by means of a regression equation specified in Howe and Linaweaver[6], applicable to the demand for summer sprinkling water in the eastern United States.

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[6] C. W. Howe and F. P. Linaweaver, Jr.: "The Impact of Price on Residential Water Demand and its Relation to System Design and Price Structure", Water Resources Research, I, 1965, 13-32.

We also included here Golf Club losses (cited as Miscellaneous in the RFF volume), primarily because:

(a) we felt that the demand for Golf Club sprinkling in a community has determinants similar to those of the demand for lawn sprinkling (i.e. both demands are generally proportional to the number of homes in low density residential areas, and

(b) losses incurred by Golf Clubs are primarily borne by their members, who fall into the domestic sector.

LOSS TYPE 6. Permanent Losses: Industrial Sector. The only heading here reflects the "claimed costs of all permanent water-use adjustments, ...(such as) cooling towers for the recirculation of cooling water; wells drilled to increase the plant's independent supply capability; process-water recirculation systems; additions to existing dams; new dams; installations of air-cooled window air-conditioners, and others." In order to measure the costs of these adjustments, the RFF team calculated the return on these investments measured in terms of savings on future water bills discounted at the rate of 20% and subtracted the costs (including both the investment costs and the discounted operating costs of these systems). Even at this rather high interest rate, the RFF study found that most emergency investments undertaken by industry were profitable. Even though the communities studied saw about $600,000 in industrial water-saving or water-yielding investments, these systems provided benefits, not losses, of about $200,000. Particularly profitable were investments undertaken to recirculate water, with a net return of about $260,000 on $450,000 when the project was evaluated at a discount rate of 20%. The RFF volume concludes that "managers do not seem to have been aware of these opportunities until the crisis atmosphere of the drought drew their attention to them."

LOSS TYPE 7. Permanent Losses: Domestic Sector. Like industries, certain households made emergency water supply investments in order to shield themselves from the effects of the drought. There appear to have been no domestic investments undertaken to control consumption (i.e. recycling), and these investments which were undertaken to provide

new, independent sources of water appear not to have been profitable. This implies fairly large losses for this sector.

Permanent Losses: Other Sectors. While investments of varying profitability were undertaken by sectors outside of the industrial and the domestic sectors, we were unable to split out the relevant information about these investments from the data given in the RFF study. In any case, the investments by other sectors were quite small and will not distort our estimates by much even if they are handled as annual impacts.

The losses experienced by two specific communities are presented in Table 9. One aspect of these losses deserves special consideration: Can losses for a number of firms be summed to yield losses for the industrial sector as a whole? For example, in a hypothetical situation where a serious labor shortage exists, losses of value added in industries forced to restrict operations due to water shortage may be cancelled by gains in value added by industries which profitably hire the labor released. The RFF estimates presented here apply to the case where all value added is lost when a firm is forced to shut down its operations. It is possible to look at the entire system shortage and make a series of alternative assumptions by which people and resources can be transferred either to non-water-dependent production units or to production units outside the shortage area. In this way the system losses can be, in fact, less than the full losses of firms suffering the shortage. For our purposes, however, we are working with estimates of the cost of shortage; no benefits are reaped from stimulation occurring in non-shortage areas or in non-water using activities as a consequence of the slowdown.

Table 9. Losses for Two Data Communities as a Result of the 1962-1966 Drought (in 1965 dollars)

Annual Categories	Fitchburg	Pittsfield
Industrial Business Losses & Other	171,400	17,700
Municipal Emergency Supply & Other	155,000	33,500
Commercial Losses	2,600	14,600
Domestic Sprinkling Losses	54,400	48,700
Permanent Categories		
Industrial Investment	(53,800)	27,300
Domestic Investment	30,200	49,100

Source: Russell et al., Drought and Water Supply

Relating Losses to Other Communities

The previous section described how losses were measured and tabulated for the communities studied by RFF. Here we seek measures compatible with the characteristics of communities in our sample to which previous losses can be related. Once we identify a measure, say, total value added in manufactures, it is likely to be proportional to the losses suffered in the industrial sector at a given level of shortage. We then can use that information from the RFF detailed study to estimate future impacts on any other comparable community.

We assume that for losses (L_1) in the i^{th} category, there exists some loss-base measure of, say M_i, such that the loss ratio L_i/M_i is likely to be the same for all communities at a given level shortage.

Further, we assume that the loss ratio (L_i/M_i) increases proportionally with the magnitude of the shortage, or that for each type of loss we can find a shortage coefficient (c_i) which, when multiplied by the level of shortage, gives us the expected loss ratio at that level of shortage. This means,

$$L_i/M_i = c_i s$$

where (s) is the percent of shortage. The strategy we follow here is to find some good loss base for each loss category measure, and then to estimate the coefficient c_i from data for the communities studied by RFF. Once the c_i's are determined, we can use the value of the measure for other communities to estimate what their losses are likely to be.

A. Measure for Annual Losses

Type 1. Industrial Business Losses and Other

Magnitude is likely to depend on two major factors--how much value added the community has to lose in the first place, and how much of this value added is based on water usage. A measure has been developed which takes these two likely determinants into account. It is based on the assumption that water shortage affects "heavy water using" industries twice as severely as it does firms outside that classification. Industries in the "heavy water using" group were:

Food and Kindred Products
Textile Mills
Paper and Pulp
Chemicals
Rubber Products
Primary Metals

In each case, these were included because they use water in excess of 0.3 billion gallons/employer/year. (Census of Manufactures, 1963, Massachusetts Data.)

The measure for this category was chosen as:

$$M = 3 \times \text{Value added in Heavy Water Using Manufactures} + \text{Value added in Other Manufactures}$$

This amounts to assuming that a given level of shortage causes three times as large losses per value added in the heavy water using industries as it does for all other manufacturers. The figure "3.0" was chosen since specific information on the losses was not available on a sector-by-sector basis, and yet we felt it necessary to introduce into our analysis the obvious fact that industries that depend heavily on water will suffer relatively more serious damages in the event of shortage. These industries also use - on the average - three times as much water per dollar of value added as do industries belonging to the other manufacturing group. Data used to find actual values for this measure (as well as for the others that follow) in the RFF study communities of Pittsfield and Fitchburg was taken from (1) the Census of Manufactures, 1963, (2) the appropriate City and Town Monographs, Massachusetts Department of Commerce and Development. The actual coefficients developed from these measures and the observed losses during the 1962-1966 drought appear in Table 8.

Type 2. Municipal Losses

The measure chosen was the size of the municipal water demand in mgd. The categories here include Emergency Supply Costs and Other, plus Tree Losses suffered by the towns.

Type 3. Municipal Revenue Losses

For this category we chose not to use the data provided in the RFF study, but rather to develop data individually for our sample communities and apply observed markup coefficients in those towns to the 66 receiver communities.

Data on water sales revenue and payments for water purchased from the MDC were collected by telephone from all towns in the sample. We obtained a markup by subtracting payments to the MDC from the revenue imputed to the MDC supplied water (assuming in effect that both MDC supplied and locally supplied water were sold at the same price).

For towns which are not presently in the MDC system, we used the average markup rate for towns in the system. Markup rates were assumed to remain constant until the year 2020. Changes in the price of water would present formidable analytical problems with respect to estimating the price elasticity of demand, and would bring significant changes in the projected demand figures themselves. The question of how water demand responds to increased prices needs investigation but lies outside the scope of the present study.

The measure here used was the amount of water that the towns were not able to sell because of restrictions. This amounts to estimating the difference:

Unsold Water = Unconstrained Demand - Restricted Realized Demand

We stress here that, unlike the other measures of concrete losses, this measure counted losses not on the basis of the realized baseline, but rather on the basis of the potential, unconstrained baseline water demand. In this one case it was meaningful to talk about losses due to the deviations as concrete losses.

We made no estimate of the benefits gained from not selling the water, e.g. those from lowered municipality expenses for pumping and distribution network maintenance. This assumes that (a) the distribution network would have been large enough to handle all the needed water, and (b) the variable costs saved by not delivering the unavailable water were small.

In Section 4.7.2 we shall, however, make an estimate of money saved as a result of foregone wastewater treatment, primarily because

adequate facilities do not exist at present, and will have to be built to handle whatever demand the future brings.

Type 4. Commercial Business Losses

The measure chosen here was employment outside manufacturing corrected for productivity changes over time.

Type 5. Domestic Sprinkling Loss

The number of single-family dwellings was taken as a measure for the potential sprinkling loss base in a community. While not all single-unit dwellings practice sprinkling extensively, and some multi-unit dwellings do, we nevertheless feel that this variable effectively catches the combination of density, value of dwellings, and other measures which might more fully explain the sprinkling demand.

B. Measures for Permanent Losses

Type 6. Industrial Investment

The amount of investment undertaken is related to the shortage faced by the industrial sector. The measure applied here is the amount of industrial water shortage in mgd's found as industrial water use times shortage.

Type 7. Domestic Investment

Like industrial investment, we assume that losses will be related to the magnitude of shortage faced by domestic water consumers. A measure developed for this is the size of domestic water shortage, in mgd.

Table 6 outlines the measures for each category of loss, presents estimates of the shortage coefficient derived from data for Fitchburg and Pittsfield, and then gives the average of these coefficients used in the present study.

C. Transposing Measures

Assuming that the loss coefficients in Table 10 remain stable over time, we can apply the experience of Fitchburg and Pittsfield to other communities provided that we have the appropriate loss-base measure projections. In the case of the present study, we need fore-

casts of these measures for the 1982-1990 period during which MDC communities will face a shortage of water.

For the annual losses, all we need are the projections (for the year t) of (a) the appropriate measure (M_i^t), (b) the percent shortage the community faces (s^t), and (c) the coefficient c_i:

$$L_i^t = c_i M_i^t s^t$$

For permanent loss categories the situation is slightly more complicated. Once investments have been made to adjust to a certain shortage, they will not be made again unless the shortage itself changes. Thus, losses resulting from investments due to water-shortage in a given year will be the difference between the total investment required due to the shortage of that year, less the total investment that was required to cope with the shortage of the previous year. Permanent losses can be found for year t as follows:

$$L_i^t = c_i m_i^t s^t - c_i m_i^{t-1} s^{t-1}$$

We have distinguished between the two types of losses (annual and permenent) in order to allow for differential treatment.

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Table 10. Loss Categories, Loss-Base Measures, Loss Coefficients

Type No.	Category	Loss-Base Measure	Loss Coefficient Estimates (in $000/base unit)		
			Fitchburg Data	Pittsfield Data	Average
1	Industrial Business Losses & Other	3 x Value added in Heavy Water Using Manufactures + Value Added in Other Manufactures ($ mill)	0.88	0.20	0.54
2	Municipal Emergency Supply & Other	Municipal Water Demand (mgd)	24.5	7.2	15.9
3	Municipal Lost Revenue	Water Not Sold (mgd)	Estimated by Sample Town; Range: 22.0 - 102.0		
4	Commercial Losses	Value Added in Non-Manufacturing	0.053	.326	.199
5	Domestic Losses	Single-unit Dwellings (000)	11.9	8.75	10.4
6	Industrial Investment	Industrial Water Shortage (mgd)	-410.7	51.1	0.*
7	Domestic Investment	Domestic Water Shortage (mgd)	159.8	491.0	325.5

* The strict average of industrial investment losses turned out to be negative, implying large benefits. We felt that in the long run the coefficient was unlikely to stay negative, so we set it at 0.

4.3.3 Losses to the System as a Whole

Two major kinds of impact have not been discussed in the community context. These impacts pertain to the MDC system as a whole, and can only artificially be attributed to individual towns in the system. Consequently, we shall deal with them on an MDC-wide level in Section 8.2.

The first major aspect is the cost to the MDC of unavailable water, i.e. revenues lost by the MDC as a result of the restrictions.

The second aspect is more important. In evaluating the cost of shortage, we seldom consider the environmental costs of providing additional water to meet "potential demand". The water which is provided will probably be discharged in polluted form, and, consequently, the environmental damage caused by increases in water demand must enter our calculus. Fortunately, we need not quantify such intangibles as the value of clean water, for we can calculate the cost of returning a certain quantity of water to the environment in reasonably clean form. Thus we can impute the avoided costs of sewage treatment as a benefit gained from the water shortage. Only in this manner can we be sure that the external costs of environmental degradation are included in our analysis. These two additional, system-wide impacts are fully analyzed in Section 8.2.

4.3.4 Comments on Losses Attributable to Deviations

Returning for a moment to how the decision to relocate may be analyzed in economic terms (Figure 2), we can get some idea of the magnitude of relocation cost that is consistent with our loss data and our assumptions about deviations from the trend (i.e. non-realized expansion, or actual contraction).

In Figure 5 we draw Figure 2 again, but now losses and relocation costs appear in present values instead of imputed annual costs. If the discount rate is about 20%, the present value of losses may be in the area of 6 or 8 times their annual magnitude, depending on how quickly restrictions, and consequently losses, are expected to rise.

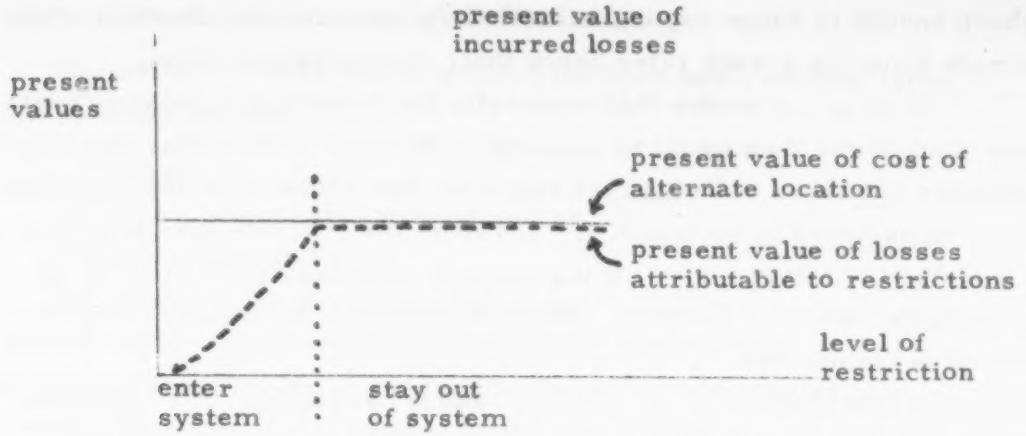

Figure 5. Decision to Stay Out of the System

In terms of Figure 5 we have no idea what general relocation costs are (for the reasons cited in Section 4.3.1), but have computed the "concrete loss" function in Section 4.3.2. In addition, in Section 4.3.1 we have made some assumptions about what level of restrictions are likely to drive activities from the system. Roughly speaking, the "maximum restriction tolerated" may be related to the response functions of Section 4.3.1 (Figures 3, 4 and Table 5) as the restriction level at which only 50% of the unconstrained activity remains.

From a knowledge of the "incurred loss" function, and a guess at the "maximum restriction tolerated", we may now work backwards to see what the relocation would have had to look like to explain the response functions of Section 1. If we know the restriction level at which people leave, and concrete losses at that level, and if we assume that the choice to leave is economic and rational, the cost of relocation must be roughly equal to concrete losses at the maximum tolerated restriction level.

Putting some numbers into this analysis, we would impute the cost of relocation at about $10,000 per $million value added for the economic activities, and about $300 - $500 for persons (using a 5% discount rate). These costs of relocation do not, of course, necessarily refer to actual leaving, but rather apply to decisions not to expand, or not to enter the system. In our computations the changes in restrictions are not

sharp enough to cause rapid contractions in the various activities--they simply limit the growth rates below their unconstrained trend.

Even so, it seems that especially the industrial relocation costs are much lower than would be expected. We must stress that these figures are not based on any direct analysis, but follow from the response function assumed in Section 4.3. and from the concrete loss functions estimated in Section 4.3.2. If the present estimates are felt to be unreasonable, we must question either the response functions or the loss functions themselves.

If this analysis is acceptable--and it has enough "if's" to make one uncomfortable--the losses that can be attached to deviations from trends are very small indeed. From the viewpoint of individual actors, whether a business decision maker or a potential resident, actual annual losses due to not entering or leaving the system amount to less than 1% of value added, or (in the case of persons) about 1% of their income. What one decides to count as the losses to some fictional accounting unit ("the Region") is another matter altogether.

Finally, whenever we speak of losses we must recall that we can count losses only when they exceed the cost of the unavailable water. This is so because the value of the water not available has already been counted as a loss in concrete loss Type 7 (for municipalities) and in Section 4.7.2 for the entire MDC system. An example may be useful here. Suppose that X is prevented from buying a gallon of water at its usual price of $10. If X now loses $20 as a result of not having the gallon, under the accounting system used here, X can merely claim $10 of losses. But a $5 loss is claimed by the municipality that could have sold the water had the MDC provided it (town markup), and a further $5 is claimed by the MDC which could have sold it to the municipality, had it been available. Thus the full amount of damage ($20) is eventually counted.

In the loss estimates presented in this study, the value of unavailable water (i.e. unconstrained demand less actual amount available) is counted as a loss already, and therefore deviation losses must be computed net of the cost of the unavailable water.

4.4 Projection of Unconstrained Activity Base

Our objective here was to project the four basic activity types crucial to water demand:

(1) population
(2) heavy water using manufacturing
(3) other manufacturing
(4) commercial (non-manufacturing)

We needed value-added measures for the last three groups so that we could account for changes in production rather than in employment--how much water an activity uses is more likely to depend on how much is actually produced, rather than on how many machinery operators are involved.

The basic sequence of these projections was as follows:

(1) forecast population
(2) forecast total employment
(3) forecast shares of employment by sector
(4) forecast value added per employee
(5) forecast value added by sector

Each stage of the projection process used information from the previous stage of projections, as well as other information as needed.

4.4.1 Projection of Population for the 66 Cities

For the period 1970-1990 projections developed by Camp, Dresser, and McKee in a water study for the Metropolitan Area Planning Council (MAPC) were used. [7]

For the period 1991-2020 we found no individual city forecasts. Even in the case of the more heavily researched sample representatives, only Natick's Master Plan was found to contain forecasts so far into the future. Forecasts of population growth for the whole of the study area

[7] Camp, Dresser, McKee: Projected Needs and Current Proposals for Water and Sewer Facilities, 1969.

were available from a study made by MAPC.[8] We applied these forecasts to individual communities in the following manner:

$$(5.1) \qquad G_i^t = \alpha_i G_{MA}^t \qquad \text{for } 1991 \leq t \leq 2020$$

where G_i^t expansion rate of the i^{th} community at time t

G_{MA}^t expansion rate of the Metropolitan Area at time t

$$(5.2) \qquad \text{where } \alpha_i = \frac{G_i^{1990}}{G_{MA}^{1990}}$$

or α_i is the last observed ratio (for the year 1990) of the expansion rate of the i^{th} community to the expansion rate of the area.

Thus, if a community expanded by a factor of 1.04 in 1990, and the whole area expanded by a factor of 1.02 during the same year, we forecasted that after 1990 the community would continue to expand with a factor equal to 1.02 (=1.04/1.02) times the expansion of the whole area.

4.4.2 Projection of Total Employment for the 66 Cities

We did not project employment directly, but rather the ratio of employment to population of each town. This ratio multiplied by population projections served as the projected employment for the 66 cities.

The ratio was projected in a two-stage manner--first for sample cities, and then for all receivers.

- Employment Projection for Sample Cities

For most of the sample cities a strong observed trend was visible in the ratio of employment to population during the 1960-1970 period. No forecasts were available for dates into the future except, again, for

[8] Metropolitan Area Planning Council: Economic Base and Population Study, Vol. I.

best copy available

Natick and for the whole Metropolitan Area. The latter showed no significant trend.

The fact that the overall ratio of total employment to population in a region is relatively constant reflects nothing more than that the labor force participation of individuals is not significantly changing.

To extend this to all sample communities, however, would imply using the highly questionable assumption that cities will not become any more or less commercial in the future than they are now--an assumption clearly contrary to the observed trend of increased commercial activity in certain cities despite declining population and vice versa.

We chose instead to extrapolate the trend of the 1960's into the future for each sample city, using the method of decaying trends.

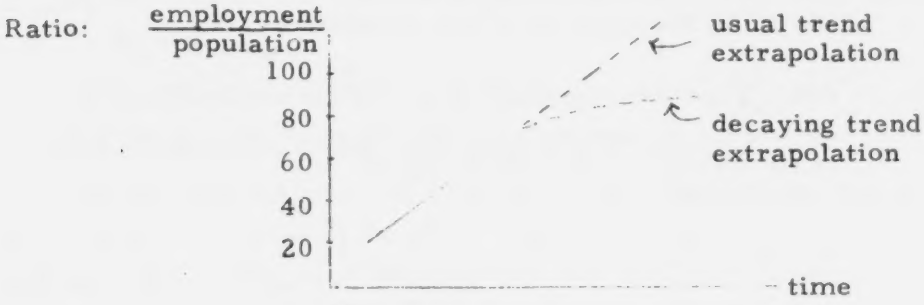

Figure 6.

In particular, we assumed that if the ratio grew at a rate of 40% from 1960-1970, it would grow at a lesser rate, 8% during 1970-1980, with still a smaller rate, say 1.6% during the next decade, etc. This says that

$$g_i^t = g_i^{1970} \cdot \alpha^{t-1970} \tag{5.3}$$

where g_i^t is the growth rate of the ratio for the i^{th} community and α is an arbitrary constant we chose to set at 0.2.

Thus we projected the ratio of employment/population (call it r) using the g's projected by equation (5.3):

(5.4) $$r_i^t = r_i^{t-1} \cdot (1 + g_i^t)$$

Employment (E_i^t) in turn was projected by using the population projections (P_i^t) from the previous stage.

(5.5) $$E_i^t = r_i^t \cdot P_i^t$$

- Employment Projections Extended to All Receivers

Insofar as we were unable to obtain data needed to make the projections of Section 5.2.1 for all cities, we estimated the ratio of employment/population for each city from the projected magnitude of the coefficient for the representative city of the cluster.

Let r^t be the ratio for a non-sample city,

and r_{i*}^t be the projected ratio for the representative

of i's cluster. Then we assumed:

(5.6) $$r_i^t = \alpha \cdot r_{i*}^t$$

where $\alpha = r_i^{1970} / r_{i*}^{1970}$,

or, the constant α was estimated from the observed (1970) ratio of r_i to r_{i*}.

Having thus obtained employment/population ratios for <u>all</u> receivers, we could again use equation (5.5) to project employment for all receivers.

4.4.3 <u>Projection of Sectoral Employment for the 66 Cities</u>

Once again we resorted to a two-stage process for estimating the breakdowns of employment into the three sectors need for this analysis.

- Projections of Sectoral Shares for Sample Cities

Let the share of sector j in the total employment of community i be represented by ${}_jS_i^t$. The sector j has a general development trend obtained from the MAPC Study cited earlier; this is ${}_jS_{MA}^t$, or the share of sector j in the overall region's employment.

We assumed a constant relation between the share of the activity in a city, and the share of the activity in the Metropolitan Area, namely:

(5.7) $$ {}_jS_i^t = \alpha_j {}_jS_{MA}^t $$

where $\alpha_j = {}_jS_i^{1970} / {}_{MA}S_i^{1970}$,

or the constant α was estimated from the observed (1970) ratio of ${}_jS_i$ to ${}_jS_{MA}$.

- Projections of Sectoral Shares Extended to All Receivers

For the non-manufacturing sector (j=3), information was available on the 66-city level of detail, and we used formula (5.7) directly to estimate the employment share of the non-manufacturing sector in all 66 communities.

For the share of manufacturing employment in each of the two manufacturing sectors considered in our study, we assumed (for lack of an alternative) that the two sectors exist in the very same proportion in all cities in the cluster, and thus set the share of manufacturing employment in each of the two manufacturing sectors equal to the projections for the sample communities:

(5.8) $$ {}_jS_i^t = (1 - {}_3S_i^t) \frac{{}_jS_{i*}^t}{(1 - {}_3S_{i*}^t)} \qquad j = 1 \text{ and } 2 $$

where the subscripts refer to:

j = 1 heavy water using manufacturing
j = 2 other manufacturing
j = 3 non-manufacturing.

Thus employment projections ($_jE_i^t$) for sector j at time t in city i could now be made for all receivers, using projections of section 5.2.2:

$$(5.9) \qquad {}_jE_i^t = {}_jS_i^t \cdot E_i^t$$

4.4.4 Value Added Projections for the 66 Cities

For each sector we projected value added per man by using (a) the 1963 Census Statistics, Massachusetts data, and (b) the MAPC projections of productivity increase over the 1963-2020 period:

$$(5.10) \qquad v_j^t = v_j^{1963} \cdot p_j^t$$

where v_j^t is value added per man at time t,

v_j^{1963} is obtained from census data,

p_j^t is a productivity index obtained from the previously cited MAPC study.

We must observe here that both the Census and the MAPC provided the information on v's and p's for a more detailed sectoral breakdown; this information was averaged (weighted by area employment for the time t) to yield v's and p's for our more aggregated sectoral classification.

Assuming that value added per man is the same for each city (given, of course, time and sector), so that the v_j^t's could now be applied to the sectoral employment projections of Section 5.3.2 to give sectoral value added projections for each city ($_jVA_i^t$):

$$(5.11) \qquad {}_jVA_i^t = v_j^t \cdot {}_jE_i^t .$$

4.5 Projections of Unconstrained Water Demand and Local Water Supply

While projections for water demand were available until 1990 for the system as a whole (supplied by the Corps) and for individual receivers (from the Camp, Dresser, and McKee study cited earlier), there was no projection available for either the system or the communities after 1990. Consequently we had to construct water demand projections for the period 1990-2020, and also local water supply projections for the communities studied in order to estimate demand for MDC supplied water.

4.5.1 Unconstrained Demand Projections

We assumed that the water demand (W_i^t) for city i at time t could be written as the sum of uses in the various activities projected for the city:

$$(6.1) \qquad W_i^t = {}_pC_i^t \cdot P_i^t + \sum_{j=1}^{3} {}_jC_i^t \cdot {}_jVA_i^t$$

where ${}_pC_i^t$ domestic consumption coefficient in i at t,

${}_jC_i^t$ consumption coefficient of j^{th} economic sector in i at time t.

Our task, then, was to project the coefficients (C's) and then compute water demand according to (6.1) using projections of VA and P. The strategy we followed was to obtain preliminary estimates of the C's, and then to calibrate these initial estimates so that they would in effect "explain" the projections we had for the 1970-1990 period from sources cited earlier. After 1990 the calibrated coefficients were allowed to "go on their own"; i.e. we derived W_i^t's directly from equation (6.1) for $t > 1990$.

- Initial Coefficient Estimates

The current (appr. 1970) coefficient estimates were determined as follows:

(1) The volume of domestic water consumption was collected for all sample cities by telephone interview with their respective water departments. This was divided by population to yield a per capita consumption coefficient.

(2) The Massachusetts water-use data from the 1963 Census of Manufactures was used to obtain water consumption estimates for the two manufacturing sectors.

(3) Non-manufacturing economic activity was assumed to have coefficients equal to the "other" manufacturing sector (i.e. manufacturing excluding heavy water users).

These current coefficients were projected into the future using data in another RFF study, Wollman and Bonem's national survey of water adequacy.[9] That study provides regional indices of water intake coefficients for economic sectors as well as for domestic consumption. Their New England estimates were used here.

These index numbers extend to 2020, and some interpolation was done to get index values for years not explicitly considered in their work. Our current coefficient estimates were projected into the future using the Wollman/Bonem indices to introduce changes over time.

- Calibration of Coefficients

We proceeded through three stages in calibrating the coefficients developed in Section 6.1.1. The first stage involved the proportional rescaling of the economic sectors' coefficients for each of the sample cities so that they would in fact yield total non-domestic water use.

[9] N. Wollman and G. W. Bonem: The Outlook for Water: Quality, Quantity, and Growth, Resources for the Future, 1971.

From the telephone survey cited above, we had non-domestic water use estimates for the sample cities for the year 1971. Coefficients for all future years were scaled in proportion to the scaling necessary to yield non-domestic use in 1971.[10]

After the first stage of calibration, the coefficients for the sample cities (now consistent with 1971 demand data) were assigned to all the other members of their respective clusters. We now went on to the second stage of calibration, and scaled each town's coefficients so that the total demand computed via equation (6.1) would equal the Camp, Dresser, and McKee projections for 1970-1990.

Yet a third stage of calibration was necessary because the Camp, Dresser, and McKee projections of MDC demand (i.e. total water demand less locally supplied water for the communities served by the MDC) did not fully agree with system demand as estimated by the Corps. We assumed that

(a) all potential receivers enter the MDC system between 1971 and 1976,

(b) the Corps' projections for system demand are correct, and

(c) the Camp, Dresser, and McKee projections of local supplies are correct.

According to these assumptions we scaled down all coefficients to yield a figure for total water demand (summed over receivers) which exceeds local water supplies (summed over receivers) by an amount equal to the Corps' projection of the demand for MDC water when all receivers are served.

Two observations are due here. First, the projections of demand were actually performed only for the years at the start of each decade (1970, 1980, 1990, etc.) and were interpolated for years within the decades. As a result, although our demand data (all receivers served) agree with the Corps' estimate for these benchmark years, our data do not exactly

[10] This stage of scaling did not need to be applied to the domestic coefficient, because that coefficient was in fact developed directly from the domestic water use data.

agree with the Corps' estimate for years within each decade.

Second, at the third stage of calibration we had a choice of alternatives in calibrating to achieve consistency with the Corps' system demand estimates: (a) all receivers are served, or (b) presently served members only are served. By calibrating according to option (a), we in fact destroyed the strict equality between our system demand projections and those of the Corps when no new communities are admitted the system.

There was, of course, no way of calibrating beyond 1990. Indeed, the whole exercise would have been unnecessary had we had demand data after that. In effect, our coefficients after 1990 are the fully calibrated coefficients for 1990 extrapolated until 2020 using the Wollman-Bonem indices of coefficient change.

4.5.2 Local Supply Projections

The Camp, Dresser, and McKee study provided estimates of available local water supply for each of the 66 receivers until 1990. For years after 1990, we used the "decaying trend" method of estimating local supplies. (See Section 5.2.1.) This means, in effect, that if a community's local yield is declining in the 1980-1990 decade, we assumed that it would continue to decline thereafter, though at a decreasing rate.

This may mean that we have seriously underestimated local supply sources, especially if we expect the wastewater quality to improve in the area. The reason for this is that the Camp, Dresser, and McKee study bases its local supply changes on the assumption that MDC water will be readily available. We suspect that often the decline in local yield is not due to conditions of the source, but rather due to the convenience or profitability of buying water from the MDC itself.

Accordingly, we feel that the Corps', and thus necessarily our, estimate of MDC demand may be overstated by as much as 10-30% if conditions make it sensible to keep local sources operating at their technical capacity.

The projected local supplies are presented in Table 11.

Table 11. LOCAL WATER SUPPLY PROJECTIONS (MGD)

	COMMUNITY	1970	1980	1990	2000	2010	2020
1	ARLING	-0.00	-0.00	0.0	0.0	0.0	0.0
2	BELMON	-0.00	-0.00	0.0	0.0	0.0	0.0
3	BOSTON	-0.00	-0.00	0.0	0.0	0.0	0.0
4	BRKLNE	-0.00	-0.00	0.0	0.0	0.0	0.0
5	CHLSEA	-0.00	-0.00	0.0	0.0	0.0	0.0
6	EVERET	-0.00	-0.00	0.0	0.0	0.0	0.0
7	LEXING	-0.00	-0.00	0.0	0.0	0.0	0.0
8	LYNFLD	0.0	0.0	0.0	0.0	0.0	0.0
9	MALDEN	-0.00	-0.00	0.0	0.0	0.0	0.0
10	MRBLHD	-0.00	-0.00	0.0	0.0	0.0	0.0
11	MEDFRD	-0.00	-0.00	0.0	0.0	0.0	0.0
12	MELRCS	-0.00	-0.00	0.0	0.0	0.0	0.0
13	MILTON	-0.00	-0.00	0.0	0.0	0.0	0.0
14	NAHANT	-0.00	-0.00	0.0	0.0	0.0	0.0
15	NEWTON	-0.00	-0.00	0.0	0.0	0.0	0.0
16	NORWOD	-0.00	-0.00	0.0	0.0	0.0	0.0
17	QUINCY	-0.00	-0.00	0.0	0.0	0.0	0.0
18	REVERE	-0.00	-0.00	0.0	0.0	0.0	0.0
19	SAUGUS	-0.00	-0.00	0.0	0.0	0.0	0.0
20	SMRVLE	-0.00	-0.00	0.0	0.0	0.0	0.0
21	STNHAM	-0.00	-0.00	0.0	0.0	0.0	0.0
22	SWPSCT	-0.00	-0.00	0.0	0.0	0.0	0.0
23	WALTHM	-0.00	-0.00	0.0	0.0	0.0	0.0
24	WATER	-0.00	-0.00	0.0	0.0	0.0	0.0
25	WNTHRP	-0.00	-0.00	0.0	0.0	0.0	0.0
26	CAMBRG	13.61	13.75	13.70	13.69	13.69	13.69
27	CANTON	2.85	2.96	3.00	3.01	3.01	3.01
28	NEDHAM	2.50	2.92	3.40	3.51	3.54	3.54
29	PABODY	3.11	3.24	3.10	3.07	3.07	3.07
30	WAKFLD	0.98	1.01	1.00	1.00	1.00	1.00
31	WESTON	0.77	1.29	2.10	2.37	2.43	2.44
32	WNCHTR	0.81	0.78	0.70	0.69	0.68	0.68
33	CLNTON	-0.00	-0.00	0.0	0.0	0.0	0.0
34	CHICOP	-0.00	-0.00	0.0	0.0	0.0	0.0
35	FRMGHM	2.07	2.12	2.10	2.10	2.10	2.10
36	LNCAST	0.41	0.61	0.90	0.99	1.00	1.01
37	LECMIN	5.77	6.03	6.30	6.36	6.37	6.37
38	MRBOGH	1.54	1.64	1.60	1.59	1.59	1.59
39	NTHBOR	0.55	0.87	1.20	1.29	1.31	1.32
40	STHBRH	-0.00	-0.00	0.0	0.0	0.0	0.0
41	STHHAD	-0.00	-0.00	0.0	0.0	0.0	0.0
42	WILBRA	-0.00	-0.00	0.0	0.0	0.0	0.0
43	ASHLAN	0.84	0.13	0.20	0.22	0.23	0.23
44	AVON	0.48	0.50	0.80	0.89	0.92	0.92
45	BOLTON	1.36	0.74	0.40	0.34	0.36	0.36
46	BRNTRE	4.02	3.08	3.00	2.98	2.98	2.98
47	DEDHAM	2.95	3.24	3.10	3.07	3.07	3.07

COMMUNITY	1970	1980	1990	2000	2010	2020
48 DOVER	0.24	-0.00	0.0	0.0	0.0	0.0
49 HCLBRK	1.01	1.42	2.00	2.16	2.20	2.20
50 HCLSTN	0.59	0.11	0.10	0.10	0.10	0.10
51 HUDSON	1.34	1.17	1.10	1.09	1.08	1.08
52 LINCON	0.66	0.61	0.99	0.99	1.01	1.01
53 MAYNRD	0.66	-0.00	0.0	0.0	0.0	0.0
54 MEDFLD	0.73	0.93	1.10	1.14	1.15	1.15
55 MILLIS	0.42	0.13	0.20	0.22	0.23	0.23
56 NATICK	6.74	5.02	5.50	5.60	5.63	5.63
57 NORFOK	0.04	0.10	0.70	1.52	1.97	1.96
58 RANDLP	2.15	3.14	4.60	5.03	5.12	5.14
59 SHRBRN	0.12	0.33	0.90	1.21	1.29	1.31
60 STCTON	2.64	2.39	3.00	3.15	3.19	3.19
[illegible]	1.1[illegible]	0.6[illegible]	0.0	0.0	0.0	0.0
[illegible] SUDBRY	0.61	0.13	0.20	0.22	0.22	0.22
[illegible] WELSLY	3.71	3.[illegible]	3.30	3.21	3.20	3.19
64 WSTWOD	1.03	-0.00	0.0	0.0	0.0	0.0
65 WEYMTH	4.24	4.58	4.30	4.25	4.24	4.24
66 WCBURN	5.69	4.47	5.30	5.50	5.54	5.55

4.6 Projection of Realized Activity Base: Simulation Model

The overall demand for MDC water is obviously the sum of the individual demands of served communities. In attempting to simulate the response of MDC receivers to an inadequacy of MDC supply sources, we have to consider the precise implications of MDC restrictions on each individual community.

In particular, a 30% restriction on MDC purchases implies a 30% restriction on a particular town's demand only if:

(a) the MDC applies restrictions uniformly to each community's demand for MDC water, and

(b) the town has no local sources of water.

The first condition, (a), we have assumed throughout this study--restrictions apply uniformly for all towns served. We may observe here that this is not a fair way of rationing whatever water is available, for towns which depend entirely on the MDC suffer more than those communities which have local sources of their own. The second condition, (b), we have clearly not taken for granted, and in the present section we show how the towns' local sources determined the amount by which the towns' supplies had to be restricted in face of restrictions by the MDC.

Our computer model started the search for the equilibrium MDC restriction (in a given year) with the restriction rate that would have obtained had the unconstrained trend been realized. At this MDC restriction level the model then computed what the local restriction rate would have been for each of the 66 cities had their unconstrained activity trend been realized. For example, if a city relied on the MDC for 30% of its water, and the MDC applied a 10% restriction on all of its clients, the city's actual shortage would have been 3%.

At this point, the model simulated the response of the various activities in each city to the local restriction, computing how far below the unconstrained trend the city's activities would drop at the trial restriction rate. By using the water demand equations in Section 4.5.1

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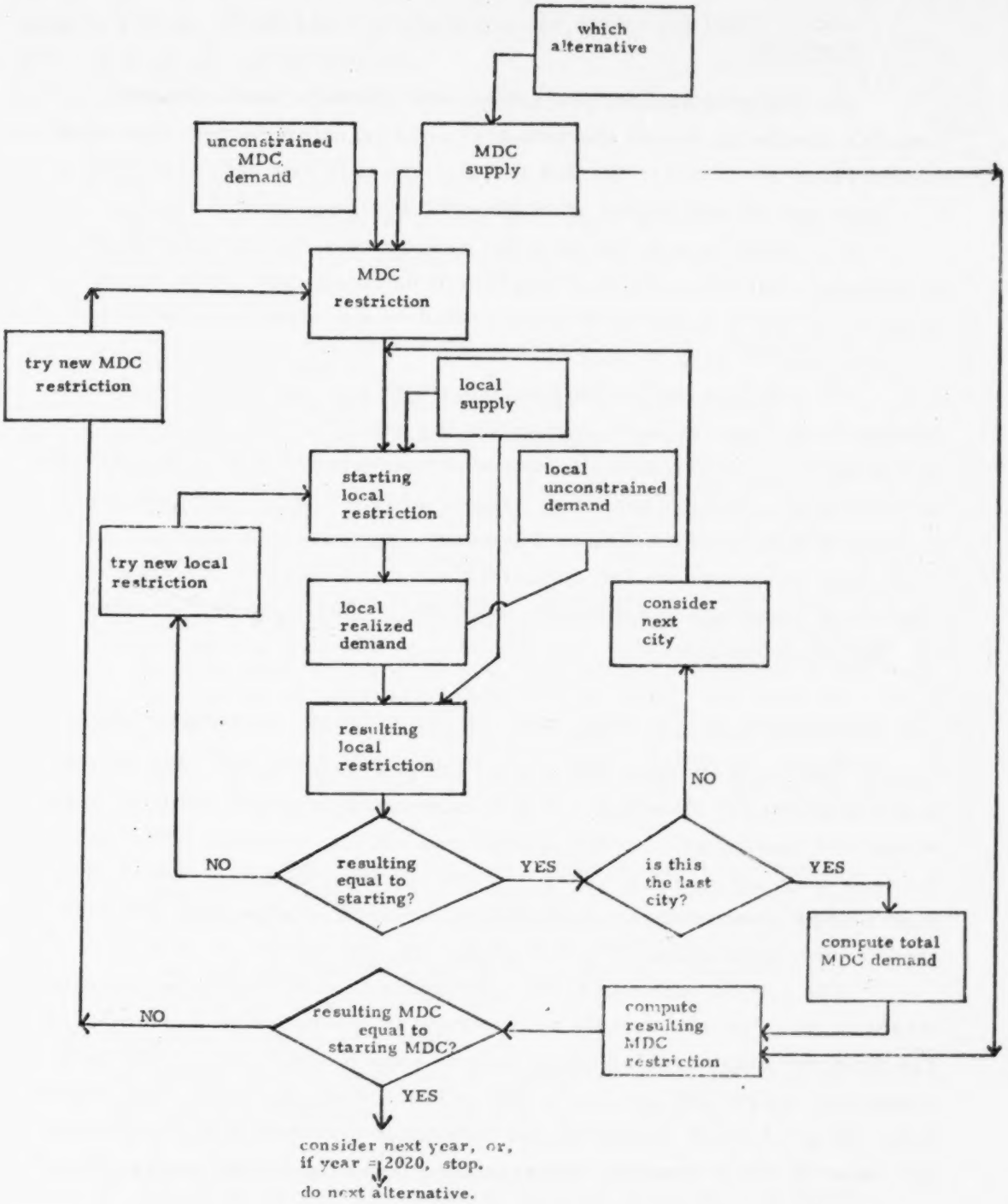
the model computed the new demand, computed the restriction implied by the new demand, and checked it against the trial rate used to start the analysis. If the starting and resulting rates were close (within 2%), the analysis ended, yielding an equilibrium value for the local restriction rate, and for the local demand for water. If the starting and resulting rates were not close, a new iteration was made with a restriction half-way between the starting and resulting magnitudes of the previous round.

After finding an equilibrium for each city, the model summed the demand for MDC water from all served cities, and computed the restriction on MDC water that would have resulted. Once again, if the starting and resulting rates were far apart, a new rate was tried. Only when the starting and resulting values were close (differed by less than 5% of the starting value) was the problem considered solved.

After thus finding an equilibrium for the system as a whole, as well as for each individual community, the model moved on to consider the next year in the analysis. The supply for the next year was determined by adding the yield of the system (which depended, of course, on whether the "go" or the "no go" alternative was studied) to however much was available in stocks. In each period, care was taken to adjust the stocks by the amount of withdrawals (or additions) that took place during the period.

The model is illustrated by the flow chart in Figure 7. It is important to remember here that temporary shortages induced by a drought were not allowed to cause demand adjustments; the demand fell below unconstrained demand only as a consequence of permanent restrictions.

Figure 7. Simulation Model



4.7 Loss Computations and Analysis

4.7.1 Methods

The realized activity projections and shortage rates obtained from the simulation model (Section 4.6) were transformed into loss base measures as described in Section 4.3.2. The only new data needed at this stage was the projection of single-unit dwellings in each town.

Such data were unavailable for each community, and therefore we assumed that the number of single-unit dwellings per capita would be equal for cities within each cluster, and we estimated the value of this coefficient for the sample cities only.

We could not project this variable with any real certainty; opposite trends are at work in changing the ratio. On the one hand, increased incomes are likely to increase the desire to live in single-unit dwellings; on the other hand, greater predicted population density is likely to force more apartment-type developments. In light of these conflicting influences we felt comfortable in assuming that the ratio of single-unit dwellings to population will remain stable for each cluster; i.e. at its 1970 value.

4.7.2 Description of Loss Estimates for Communities (Appendix Tables)

The loss estimates themselves are presented in two sets of tables in the Appendices. The first set summarizes all impacts--both concrete losses and deviations--for the system as a whole: Appendix I, 1.1 for the case when all potential receivers are admitted to the system, I, 1.2 when no new communities are admitted, for each cluster, and for each sample city, Appendices I, 2.1 through I, 2.1.2.

The second series of tables, Appendix II, describes the concrete losses in more detail, namely by loss type as discussed in Section 3.2.3. The first two sets of tables included here show a breakdown of concrete losses for "no go" and for "go", while the third set subtracts "go" losses from "no go" losses, giving the net difference (in terms of concrete losses) between these synthetic "alternatives". As we argued earlier, the

'no go" situation is something less than an alternative, since it incorporates strong, counterfactual assumptions, and is not likely to take place even if "go" is not adopted.

Attention is directed to some of the less obvious aspects of these tabular displays.

(1) All Tables:

The figures for 2000, 2010 and 2020 show losses in those calendar years alone, and not sums of losses for those decades.

(2) Summary Tables:

(a) All $ values are expressed in millions $1963. Population is in thousands.

(b) The unconstrained trend is marked "Enough Supply".

(c) Losses are counted from the viewpoint of all potential receivers, regardless of whether all potential receivers are admitted or not. Thus in the tables that show losses when the service is assumed to be provided to presently served cities only, we see a sum of the losses of cities served and cities not served.

(d) When MDC service is denied to potential receivers (i. e. only communities already served are allowed to buy water from the MDC), even the "go" alternative creates losses. Despite the fact that the water is available, those communities who are not in the MDC at present will be exposed to serious restrictions.

(e) The "go" alternative begins to become inadequate according to Table 7 of Section 4. 2. 5; this can be seen in any of the tables pertaining to sample cities that are presently served by the MDC.

(f) In the "drought" situation, we assumed that local supplies would not fall below their normal yields, and that the Tully-Northfield part of the system would not fall below 120 mgd. (See Section 4. 2. 2). In effect, these assumptions mean that only the existing MDC system yields would fall under the drought.

(3) Concrete Loss Summaries:

(a) Losses are counted from the viewpoint of all potential receivers.

(b) Business investment losses are zero. (See Table 10 of Section 4. 3. 2.)

(c) Domestic investment losses are not proportional to the size of the shortage, but rather to changes in water availability.

Thus a large part of such investments are made when the shortages first appear. New wells are dug when restrictions are applied and maintained. Once a well has been dug to adjust to a given level of restrictions, it need not be dug again unless higher restrictions are imposed. (See Section 4.3.2)

(d) In the domestic investment category the "no go" alternative implies lower losses for some years than the "go" alternative. This happens because in the "no go" case shortages arrive only at a fairly late date, and by that time people will have made their domestic investments under "no go".

(e) City revenue losses are clearly the largest item in the concrete loss category.

(f) In terms of concrete losses, the "go" alternative is most profitable relative to "no go" in the years 1990-2010. (See Section 4.2.5.)

4.7.3 Losses for the System (Excluding Losses by Communities)

We come now to the last set of impact estimates: those pertaining to the system as a whole. Two categories are involved here: (a) revenue lost by the MDC from not being able to sell water to meet unconstrained demand, and (b) gains derived from not having to renovate the unavailable water.

- Revenue Lost to the MDC

The average price of water to the member communities was determined from our telephone interview with the sample towns' water departments. We estimated that the MDC charges approximately $43,700 per mgd per year. The loss estimate is simply this figure times the mgd difference between sales and unconstrained demand.

- Gains in Reduced Water Treatment Costs

There are two reasons for including this item in the present computations. First, the system would probably realize concrete gains from not having to clean the additional water, though these gains are not likely to be as large as the ones we show in Table 12.

Table 12, Losses for the System* ($1971 Mill)

	SERVICE: ALL RECEIVERS				SERVICE: NON-SERVED ONLY			
	Lost Revenue, MDC		Avoided Treatment**		Lost Revenue, MDC		Avoided Treatment**	
	No Go	Go	No Go	Go	No Go	Go	No Go	Go
1976	0.	0.	0.	0.	0.	0.	0.	0.
1977	0.	0.	0.	0.	0.	0.	0.	0.
1978	0.	0.	0.	0.	0.	0.	0.	0.
1979	0.	0.	0.	0.	0.	0.	0.	0.
1980	0.	0.	0.	0.	0.	0.	0.	0.
1981	0.	0.	0.	0.	0.	0.	0.	0.
1982	2.928	0.	-4.502	0.	0.	0.	0.	0.
1983	3.278	0.	-5.040	0.	0.	0.	0.	0.
1984	3.627	0.	-5.578	0.	2.535	0.	-3.898	0.
1985	3.977	0.	-6.115	0.	2.841	0.	-4.368	0.
1986	4.370	0.	-6.720	0.	3.103	0.	-4.771	0.
1987	4.720	0.	-7.258	0.	3.409	0.	-5.242	0.
1988	5.069	0.	-7.795	0.	3.671	0.	-5.645	0.
1989	5.419	0.	-8.333	0.	3.933	0.	-6.048	0.
1990	5.768	0.	-8.870	0.	4.239	0.	-6.518	0.
2000	9.090	0.	-13.978	0.	6.599	0.	-10.147	0.
2010	13.329	8.085	-20.496	-12.432	9.369	0.	-14.448	0.
2020	18.573	13.329	-28.560	-20.496	12.673	7.429	-19.488	-7.429

* Negative losses are gains; see Section 8.3.2.

** Assuming eventual treatment of 100% of the delivered water. For non-zero consumption loss rates these figures must be adjusted by a factor of 0.7.

The second reason is that the environmental damage caused by using the extra water has to be accounted for in some fashion. The natural price to put on what it costs to use clean water is the cost of cleaning it, or the amount of money it takes to return it in its original form.[11] This is an externality or cost incurred by society, yet not included in the price of a good. The environmental damage caused by using clean water and not returning it to the environment in its clear form involves such costs. If treatment is in fact undertaken, then the costs of treatment are usually external costs, i.e. not included in the price of the good used, in this case water.

However, external costs must not be neglected by competitive markets as they have been if environmental quality is to be an achievable goal. Therefore, in this analysis, we take into account external costs by imputing the value of the environmental damage that we prevent by sustaining water shortages.

But what level of cleanliness should we count as the proxy for damage prevented?[12] No feasible technique we have so far devised can totally reverse the damage caused by domestic, and especially industrial water use. But for the purposes of the present study we nevertheless have to pinpoint a magnitude. We chose the cost of a level of treatment, which, given current economic and technical feasibilities, does provide high water quality: tertiary treatment. This, indeed, is the system proposed by the Corps and others for the seriously degraded waters of New England's Merrimack. The cost estimate used comes from an Arthur D. Little study[13], and puts the cost (assuming 30% industrial waste) at 18.4¢ per 1000 gallons, or at roughly $67,200 per mgd per year.

These gains are shown alongside the revenue losses of the system as a whole in Table 12. It is important to note that the avoided

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[11] If X spills coffee on Y's suit, the value of the damage they are likely to agree on is the cost of having Y's suit cleaned.

[12] Had X spilled ink instead of coffee on Y's suit, Y could well claim that the costs of cleaning would be very large, far beyond the normal costs of cleaning suits, and possibly that his suit might never be as good as it was.

[13] Arthur D. Little, Inc.: Fostering Industrial Growth in Massachusetts, Vol. II, 1971, p. 115.

treatment gains (a) are based on treatment rates above those presently observed in the MDC area, and (b) these gains will not accrue to the MDC, insofar as (i) some of the treatment would be avoided by the several localities, and (ii) ultimately not the MDC, but rather the taxpayers (industrial and individuals) would be realizing the savings from lower sewage treatment expenditures.

4.7.4 Revised "GO, Drought" Estimates and Their Effects

In the computations explained and presented in this report it was assumed that the Tully-Northfield components of the system would not themselves suffer lower yields during the hypothetical drought considered in our analysis. New data received from the Corps is now available to replace this unrealistic assumption, but unfortunately computations have already been completed.

Rather than recompute the model, an impossibility given limitations in time and resources, we will briefly explore the likely effects of this new data on the results presented. The new yields of Tully-Northfield under "drought" are shown in Table 13. They also result in new "GO" yields under drought, as shown in Table 5.

No revision in population and value added losses are implied by these modifications, since temporary shortages are assumed to leave these variables unaffected. The results are felt by concrete losses in two of the scenarios studied:

(a) GO, drought, all receivers served

(b) GO, drought, only present members served.

For "GO all served, drought" the following changes are likely to take place:

(1) Restrictions of 12.3% and 35.6% will have to be observed in 1979 and 1980, respectively. In the original computations both of these years showed zero restrictions.

(2) The system will run out of stocks about a year earlier than projected, i.e. in approximately 1995 instead of 1996. (See Table 7.)

(3) The concrete losses associated with the restrictions suffered in 1979 will be roughly similar to the concrete losses that

the No Go, all Served system shows for normal conditions in 1982.

(4) The concrete losses associated with the restrictions in 1980, will be roughly twice the No Go, all served, normal concrete losses in 1983.

For "Go, present served only, drought" the following changes are likely to take place:

(1) Restrictions of 28.2% will need to be observed in 1980, as opposed to zero in the original computations.

(2) The system stocks will be exhausted about 2 years earlier, in approximately 2007 instead of 2009. (See Table 7.)

(3) The concrete losses associated with the restrictions can be roughly computed as:

$$\text{Losses} \approx 2 \times \{\text{No Go, Present Served, Normal, 1984} - \text{No Go, Present Served, Normal, 1983}\}$$

This can then be added on to the GO, present served, drought losses shown in the old computations (resulting there from the exclusion of certain communities rather than from restrictions).

Table 13. Revised Yields of the Tully-Northfield Projects

	Yield (mgd)
Before 1976	120
76	104
77	88
78	103
79	31
80	90
After 1980	120

4.8 Qualitative Impact Data

From the statistical standpoint, the loss results obtained by the methods described in the previous sections appear to be reliable. Again, cluster totals enjoy a higher level of confidence than representative community losses, and system totals are still more accurate than cluster results. However, to give the data added credibility, we also examined the experience of an actual community already beset by the kinds of problems anticipated in the event of prolonged water shortage. Principally, "soft data" related to social impacts were our objective. How does a community respond to the dislocations of water use restrictions? Do citizens get more involved in planning when crisis conditions are sustained over a long period? How quickly does population growth slow in response to water-use and building restrictions? An extended interview with Stoughton's Planning Board Chairman produced both background and impact information (keyed by letter to impact categories displayed in Table 3, Impacts on Receiver Areas).

Stoughton is an industrial - residential community in the Brockton S. M. S. A. The town's population of about 25,000 is growing at a rate of more than 40% every decade, and shows no signs of a downward turn. The principal constraint on continuing growth may be an acute shortage of water. Presently municipal supplies come from five town wells; two recently completed standpipes with capacities of 10 and 2 million gallons give Stoughton about 14 million gallons of total storage. The severity of ongoing shortages are indicated by a complete ban on outside watering in effect for several years and a one-year freeze on the issuance of building permits lifted last year.

The town has been searching for water since 1955. First, an extensive drilling campaign at producing well sites was tried. When the results were disappointing, consulting engineers were engaged to search for new groundwater sources; results, negative or unacceptable because of high iron content. Last year a grant of $1.5 million funded a project to clean or replace defective distribution piping. In addition,

$150,000 was spent on a connection with Brockton and Canton water supplies. This, however, is seen as only a stop-gap measure because the doner towns can terminate the arrangement at will, whenever their capacities are strained. In general, admission to the M.D.C. system is viewed as the only permanent solution. Formal application has been made, but even favorable action means a delay of 8-10 years before Quabbin-Wachusett water becomes available.

The consequences of water deprivation have been felt across a wide range of community activities:

(A) 4.8.1 Land Use

Although no shifts in the allocations of land use type have occurred, development in the industrial category has been nearly stopped by water shortage. Interestingly, though a building ban prevented "new starts" on residential housing for a year, the rush to develop after the ban was lifted has more than wiped out any deficit.

(B) 4.8.2 Population

While our data projections for longer terms show population deficits for deviations from the "enough supply" situation, it does not appear that population growth is sensitive to short-term controls and constraints. Stoughton's in-migration continued despite the building ban and shows signs of growing even more quickly now that new housing construction has begun again.

(C) 4.8.3 Municipal Finance

Because finding water has been a top town priority, other municipal services have suffered. A sidewalk program has been indefinitely postponed and only minimal roadway maintenance and construction has occurred. Generally, expenditures have been cut as revenues from expected property taxation have dwindled. Estimates range as high as $1,000,000 in tax losses with increases in assessments covering the deficit. The cost of water has doubled in the past two

years and the municipal debt as of January 1, 1970 stood at $7,516,000 or $320 per capita. Until a mutual help agreement was reached with Easton and Sharon, adequate fire protection was a critical concern.

(D) 4.8.4 Commercial Activity

In the time observed by the interviewee, there have been no perceptible consequences for either retail or wholesale trade.

(E) 4.8.5 Housing

Since the lifting of the building ban, over 500 rental units have been built and occupied. The demand for housing has lowered the vacancy rates significantly and stimulated the construction of 3,000 apartment units and the planned development of 3,000 more. Before the ban went into effect, issuances of building permits had declined an average of about 130 units per year for two successive years.

(F) 4.8.6 Education

Two primary schools of twenty-six classrooms each have been completed in the past two years (September 1970 and 1971) to accommodate a swelling elementary-age school population. A much-needed junior high has been put off - an effect attributed to the " extraordinarily high expenditures of finding water. " As a result, the present junior high is expected to go into double sessions this coming fall.

(G) 4.8.7 Security

As the search for water has become "business as usual", citizens appear to have developed some tolerances for the inconvenience of watering bans. However, their latent insecurity about adequate supplies for fire protection and general domestic consumption have made water shortage a perennial political issue on which concern can focus. As noted above, the prevailing attitude is that "everything will be all right" once M. D. C. admission is secured and the burden

of water planning can be shifted to the Commission.

(H) 4.8.8 Community Image

Despite the general slowdown in industrial development and its second order consequences on town revenues, the average citizen perceives the water supply problem in terms of his own inability to water outdoors. Lawns and shrubbery are a waste of money, says the homeowner, and the town looks poorer for it. A general feeling of discouragement and frustration has set in and the desirability of Stoughton as a residential community has been adversely affected. So far no monetary reflections of this malaise have developed and property values are as yet unchanged by water shortage.

(I) 4.8.9 Economic Stability

Economic development has been hurt because water using industries have been turned away. This has "slightly decreased" the stability of the town because the tax base has not expanded quickly enough to keep up with demands on local revenues. Wages and prices have remained in phase with the rest of the state, but taxes have increased.

(J) 4.8.10 Industrial Activity

No Stoughton industries have left because of water shortage, but new industries (chemical plant, refinery) have gone elsewhere. Presently only non-manufacturing, non-processing firms are permitted to locate in town, and a $40 million industrial park is now two years behind in its development schedule.

From the Stoughton example, we venture to say that public participation in the water resources decision process has been only episodic and then motivated by personal fears of impending shortage. The planning responsibility, the effective and efficient operation of water systems has been left to local, state and regional water administrators. Unfortunately, however, such specialization leads to sub-

optimization and the entrenchment of philosophies and procedures in the professional water manager that make him unresponsive to changing public attitudes.[14] In fact, his very security is the confidence he inspires in the public. For though it is supremely unconcerned when supply and distribution are proceeding normally, the public becomes vengeful when the tap runs dry. Thus, certainty, predictability, minimized risk, and conservatism are the hallmarks of the prudent water purveyor.

As a result, one consequence of implementing Tully and Northfield will be the perpetuation of the tyranny that an apathetic public exercises over its water managers. Receivers will not be forced to reexamine the basic questions underlying further efforts to increase the yield of Quabbin:

- Can exponential increases in urban water consumption, domestic and industrial, be controlled?
- Do other technical alternatives such as wastewater renovation offer multiple economic returns on a larger capital investment?
- Can the assumption of some known degree of risk by system managers increase economic efficiency and stimulate water husbandry?
- Should pricing policy be reformed to a) rationalize now widely divergent wholesale water prices throughout the system, and b) reflect more accurately the market value of the next unit of water to the consumer rather than to the middle-man town distributor?
- Would water distribution strategies halt urban agglomeration in the metropolitan area and stimulate growth elsewhere?
- Can an overhaul of existing M.D.C. administrative policies broaden the scope of its responsibility and political accountability? Can true regionalism -- not just systematization of a specific agency function -- be considered a realistic option?

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14 For a good treatment of the more obvious deficiencies in a system of unalloyed professionalism, see David J. Allee, "Efficient Management Policies for Urban Water Supply," Cornell Agricultural Economics Staff Paper, October 1970.

If planners wish to cope in a normative way with urban congestion and foster healthy interdependence among the Commonwealth's cities and towns, it appears to us that the water supply issue is an excellent vehicle for progress. The self-fulfilling prophecies of swelling demand and dwindling supply need not be repeated if receivers begin to participate in planning the facilities that serve them.

Of course, more immediate and pedestrian impacts on receivers can be foreseen for the "go" condition. Once the diversion water is made available, it will be of undiminished quality and place no markedly higher cost burden on consumers.[15] More importantly, community growth associated with the kinds of industrial and commercial activities analyzed above continue uninterrupted. Schools, hospitals, shopping centers, etc., and the social interactions they offer will not be affected by water use restrictions. Indeed, and perhaps most significantly, individual and corporate behavioral patterns will remain unchanged. Barring natural catastrophe, the per capita consumption of water will rise and only industries with an economic incentive to reduce water use will strive to limit total intake by recycling. Suburban development among present and potential members will not be impeded by water scarcity (although other factors might well cause construction slowdowns), and the second-generation transportation and employment effects associated with metropolitan sprawl will be repeated. Generally, water users will experience no interruptions in service and take little note of their good fortune. Especially, it is unlikely that receivers will associate continuing supplies with the Tully and Northfield Projects specifically. The source of supply will be irrelevant.

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15 The cost-sharing arrangements for the Tully and Northfield complexes have not yet been worked out, and that fact by itself confuses the issue of impacts. Whereas substantial price hikes for M.D.C. water are considered essential by many, elimination of the welter of "equity" arrangements now governing M.D.C. - receiver relationships may prove politically infeasible.

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5.0 The Millers River Alternative

Having considered the Tully-Northfield plans in some detail, we believe that at best a cursory examination of yet another approach would be productive. As noted earlier, the absence of a "real" technical alternative (as opposed to the synthetic "no go") posed some serious methodological problems. More important, though, the attitude of the supplier area toward upstream diversions at Tarbell and Priest Brooks is sufficiently negative to make a search for mutually agreeable compromises worthwhile.

One particularly promising modification of the existing plans for the Millers Basin would be to incorporate renovated water as a potential diversion source.[1] This opens the option of freshet diversions directly from the Millers main stem and eliminates the need for one or more of the projects on the Miller tributaries. Significantly, spokesmen for supplier interests have more than once pointed to the polluted Millers as a problem beyond their own capabilities to solve. We believe there is the germ of a bargain in their predicament. Should the Corps be prepared to consider taking water at or near Athol and abandon plans for, say Tarbell and Priest Brooks, they would not only be providing the same volumes of water to replenish Quabbin as the original scheme, but they would also give the supplier area the advanced water treatment it might otherwise wait years to finance.

The outline of such a plan might be as follows:

1. Speeded implementation of secondary treatment plant construction to handle the major point source waste flows above Athol.
2. Corps-financed construction of advanced water treatment

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[1] Arguments that water quality management by receivers is the better answer are complicated by two factors: (1) the Corps is unlikely to exercise its authority to recommend such a course of action, and (2) while the M. D. C. does have authority to construct some sewage treatment works, it does not by itself have the manpower or financial resources to undertake such a program among all its members.

facilities at the same plant sites to bring effluents up to fully renovated levels.

3. Diversion works construction across the Millers above Athol.
4. Tunnel or conduit connections from the Millers diversion site to the tunnel feeding Quabbin.
5. Implementation of the West Branch Tully portion of the present Tully Complex plan to provide an additional or backup diversion capability.

In addition to these structural elements, an agreement between supplier towns and the M. D. C. to provide the former with service connections would quiet fears about future need.

Although no clearly articulated engineering plans are yet available, significant impacts for the Millers plan can be discussed in general terms.

5.1 Land Use

The acreage requirements for plan implementation would be on the order of 100 acres; 36 at the West Branch site in Orange and about 60 acres in Athol. This represents fully 1,000 acres less than the takings necessary for the whole Tully Complex. Diversion works would be located nearer to population centers, however, and some care should be exercised to consider aesthetics in design. Upland reservoirs would be avoided, and no intrusion on Royalston or Winchendon open space would occur. One factor to be considered in this alternative is the incentive to rivershore development that a clean Millers would provide. Strong zoning or other land use controls may well be necessary to realize the full potential of water access.

5.2 Municipal Finance

If the Corps underwrites the expense of tertiary treatment, these costs must be reckoned as savings for the towns who would otherwise have to bear a portion of such expenses. Particularly since advanced treatment would not likely be considered for some years,

the cost savings for construction begun in the near future may be estimated as roughly 12% per year according to present rises in the construction cost index.

5.3 Leisure Opportunities

A clean Millers River could open up important new recreational boating or body contact opportunities unless access restrictions limit such uses. It is not now known whether sound sanitary practices would permit public access, but the potential should be evaluated.

5.4 Community Image

Not the least attractive aspect of the Millers plan would be a revitalization of the supplier area's self-image. Troubled by a stagnant economy and the oppressive presence of a seriously polluted river, the immediate Athol area could draw new strength from the knowledge that "things are really happening." The chemistry of a town's spirit is difficult to predict, but it is a safe guess that its status as a water cleanup showplace would do the area no harm. This factor contrasted with the bristling hostility generated by the Tully Complex plan is a compelling argument for more detailed consideration of the Millers alternative.

5.5 Economic Stability

It should be pointed out that the simultaneous construction of several treatment facilities and then the diversion structure itself would be likely to stimulate larger and more diversified effects on the regional economy than the present project. The tunneling and concreting labor required for the Tully plan would remain unchanged, but the additional need for sophisticated treatment equipment and surface construction labor may well produce larger value-added totals over project life.

Impacts on receivers, it should be noted, are essentially the same for the Millers alternative as the Tully Complex because the volume of water supplied is the same. Whatever differences might exist relate chiefly to the need for treatment equipment and professional services vended by receiver area companies.

IDENTIFICATION AND ASSESSMENT OF SOCIAL AND ECONOMIC IMPACTS

APPENDICES

Connecticut and Millers River Basin Diversions

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e	0.115	0.059	0.105	0.125	0.129	0.131	0.138	0.146	0.163	0.153	0.169	0.164	0.188	0.191	0.186	0.270	0.358	0.471

APPENDIX I. 1.1: SUMMARY OF LOSSES

UNIT:ALL RECEIVERS

SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGC	NORMAL GC	DRAUGHT NCGC	DRAUGHT GC	POPULATION NCGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGC	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	2611.6	2611.6	2611.6	9492.1	9492.1	9492.1
1977	0.0	0.0	0.0	0.0	2628.6	2628.6	2628.6	9822.7	9822.7	9822.7
1978	0.0	0.0	14.698	0.0	2645.6	2645.6	2645.6	10153.3	10153.3	10153.3
1979	0.0	0.0	56.074	0.0	2662.6	2662.6	2662.6	10483.9	10483.9	10483.9
1980	0.0	0.0	14.935	0.0	2679.7	2679.7	2679.7	10814.4	10814.4	10814.4
1981	0.0	0.0	3.983	0.0	2701.0	2701.0	2701.0	11211.3	11211.3	11211.3
1982	6.251	0.0	4.441	0.0	2682.6	2722.4	2722.4	11387.3	11608.2	11608.2
1983	5.432	0.0	4.881	0.0	2691.7	2743.7	2743.7	11711.1	12005.0	12005.0
1984	5.652	0.0	5.332	0.0	2698.6	2765.0	2765.0	12016.5	12401.9	12401.9
1985	6.061	0.0	5.740	0.0	2718.3	2786.4	2786.4	12393.0	12798.8	12798.8
1986	6.508	0.0	6.169	0.0	2724.5	2807.7	2807.7	12690.3	13195.6	13195.6
1987	7.558	0.0	6.871	0.0	2728.5	2829.1	2829.1	12971.3	13592.5	13592.5
1988	7.734	0.0	7.327	0.0	2747.4	2850.4	2850.4	13334.1	13989.3	13989.3
1989	8.204	0.0	7.793	0.0	2749.5	2871.8	2871.8	13599.3	14386.2	14386.2
1990	8.630	0.0	8.235	0.0	2769.6	2893.1	2893.1	13966.5	14783.1	14783.1
2000	12.794	0.0	12.436	5.678	2521.2	3165.0	3165.0	18133.8	20098.5	20098.5
2019	18.749	12.662	18.253	12.413	3116.0	3390.8	3546.3	23148.9	25797.0	27326.5
2020	25.297	20.118	24.856	20.118	3384.7	3689.8	4057.8	29519.2	32962.5	37122.5

APPENDIX I. 1.2: SUMMARY OF LOSSES
UNIT:ALL RECEIVERS
SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	1.209	1.209	1.209	1.209	2583.1	2583.1	2611.6	9374.3	9374.3	9492.1
1977	0.940	0.940	0.940	0.940	2591.9	2591.9	2628.6	9673.1	9673.1	9822.7
1978	1.029	1.029	9.026	1.029	2599.7	2599.7	2645.6	9968.2	9968.2	10153.3
1979	1.144	1.144	57.784	1.144	2605.0	2605.0	2662.6	10252.3	10252.3	10483.9
1980	1.294	1.294	14.825	1.294	2603.0	2603.0	2679.7	10512.3	10512.3	10814.4
1981	1.170	1.170	3.733	1.170	2620.5	2620.5	2701.0	10886.4	10886.4	11211.3
1982	1.251	1.251	4.338	1.251	2636.4	2636.4	2722.4	11249.4	11249.4	11608.2
1983	1.358	1.358	4.991	1.358	2652.6	2652.6	2743.7	11615.0	11615.0	12005.0
1984	6.600	1.442	5.001	1.442	2640.4	2668.4	2765.0	11812.6	11976.4	12401.9
1985	6.165	1.519	5.693	1.519	2647.5	2685.8	2786.4	12118.5	12348.0	12798.8
1986	6.450	1.614	6.180	1.614	2653.7	2703.2	2807.7	12417.1	12718.2	13195.6
1987	6.895	1.713	6.625	1.713	2668.5	2719.1	2829.1	12762.1	13078.7	13592.5
1988	7.386	1.781	7.088	1.781	2670.5	2734.1	2850.4	13030.8	13437.2	13989.3
1989	7.850	1.885	7.550	1.885	2684.4	2748.8	2871.8	13371.6	13794.1	14386.2
1990	8.032	2.032	8.380	2.032	2683.6	2763.0	2893.1	13631.3	14159.6	14783.1
2000	12.469	2.898	12.227	2.898	2820.1	2963.9	3165.0	17720.9	18901.1	20098.5
2010	17.712	4.304	17.410	10.533	2992.8	3230.9	3549.3	22712.0	25067.8	27326.5
2020	24.138	17.738	23.778	17.445	3177.8	3421.9	4057.8	28539.8	31392.3	37122.5

APPENDIX I. 2.1: SUMMARY OF LOSSES
UNIT:CLUSTER NO. 1
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL ACGC	NORMAL GC	DRAUGHT ACGC	DRAUGHT GC	POPULATION ACGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED ACGC	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	201.8	201.8	201.8	233.1	233.1	233.1
1977	0.0	0.0	0.0	0.0	202.8	202.8	202.8	241.2	241.2	241.2
1978	0.0	0.0	0.752	0.0	203.7	203.7	203.7	249.2	249.2	249.2
1979	0.0	0.0	0.989	0.0	204.7	204.7	204.7	257.2	257.2	257.2
1980	0.0	0.0	0.646	0.0	205.6	205.6	205.6	265.3	265.3	265.3
1981	0.0	0.0	0.171	0.0	206.6	206.6	206.6	274.7	274.7	274.7
1982	0.303	0.0	0.193	0.0	204.7	207.6	207.6	279.5	284.0	284.0
1983	0.241	0.0	0.209	0.0	204.7	208.6	208.6	287.3	293.4	293.4
1984	0.247	0.0	0.229	0.0	204.6	209.6	209.6	294.7	302.8	302.8
1985	0.267	0.0	0.248	0.0	205.6	210.5	210.5	303.8	312.1	312.1
1986	0.282	0.0	0.263	0.0	205.4	211.5	211.5	311.0	321.5	321.5
1987	0.298	0.0	0.296	0.0	205.0	212.5	212.5	317.6	330.9	330.9
1988	0.340	0.0	0.316	0.0	205.9	213.5	213.5	326.6	340.3	340.3
1989	0.354	0.0	0.331	0.0	206.5	214.5	214.5	333.0	349.6	349.6
1990	0.380	0.0	0.354	0.0	206.5	215.5	215.5	342.0	359.0	359.0
2000	0.535	0.0	0.516	0.233	208.7	226.0	226.0	442.5	483.6	483.6
2010	0.750	0.501	0.723	0.488	209.9	228.7	239.1	557.2	612.8	643.5
2020	0.940	0.735	0.916	0.735	211.9	230.7	253.1	695.0	762.8	843.9

APPENDIX I. 2.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 1

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.030	0.030	0.030	0.030	201.6	201.6	201.8	232.8	232.8	233.1
1977	0.029	0.029	0.029	0.029	202.6	202.6	202.8	240.9	240.9	241.2
1978	0.034	0.034	0.440	0.034	203.3	203.3	203.7	248.7	248.7	249.2
1979	0.038	0.038	3.148	0.038	204.3	204.3	204.7	256.7	256.7	257.2
1980	0.043	0.043	0.643	0.043	205.0	205.0	205.6	264.4	264.4	265.3
1981	0.055	0.055	0.167	0.055	205.7	205.7	206.6	273.3	273.3	274.7
1982	0.057	0.057	0.192	0.057	206.7	206.7	207.6	282.6	282.6	284.0
1983	0.080	0.080	0.238	0.080	207.0	207.0	208.6	290.8	290.8	293.4
1984	0.324	0.076	0.230	0.076	205.9	208.0	209.6	296.6	300.1	302.8
1985	0.301	0.092	0.273	0.092	205.6	208.6	210.5	303.8	308.7	312.1
1986	0.304	0.093	0.289	0.093	205.2	209.1	211.5	310.5	317.1	321.5
1987	0.326	0.099	0.310	0.099	206.2	210.1	212.5	319.6	326.4	330.9
1988	0.359	0.116	0.342	0.116	205.6	210.5	213.5	325.8	334.7	340.3
1989	0.375	0.116	0.357	0.116	206.0	210.9	214.5	333.7	342.8	349.6
1990	0.444	0.135	0.405	0.135	205.2	211.3	215.5	339.2	350.7	359.0
2000	0.566	0.170	0.552	0.170	208.4	219.2	226.0	441.2	466.8	483.6
2010	0.757	0.224	0.740	0.468	211.7	228.9	239.1	561.3	612.0	643.5
2020	0.950	0.704	0.929	0.687	215.4	232.4	253.1	705.9	767.1	843.9

APPENDIX I. 3.1: SUMMARY OF LOSSES
UNIT:CLUSTER NO. 2
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGO	NORMAL GC	CRALGHT NCGO	CRALGHT GO	POPULATION NCGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGO	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	335.8	335.8	335.8	682.8	682.8	682.8
1977	0.0	0.0	0.0	0.0	338.1	338.1	338.1	708.0	708.0	708.0
1978	0.0	0.0	2.461	0.0	340.5	340.5	340.5	733.2	733.2	733.2
1979	0.0	0.0	8.483	0.0	342.8	342.8	342.8	758.3	758.3	758.3
1980	0.0	0.0	3.159	0.0	345.2	345.2	345.2	783.5	783.5	783.5
1981	0.0	0.0	0.841	0.0	347.8	347.8	347.8	813.7	813.7	813.7
1982	1.174	0.0	0.969	0.0	344.9	350.5	350.5	831.3	843.8	843.8
1983	1.132	0.0	1.065	0.0	345.8	353.1	353.1	856.9	873.9	873.9
1984	1.201	0.0	1.164	0.0	346.4	355.7	355.7	881.8	904.1	904.1
1985	1.294	0.0	1.246	0.0	349.0	358.4	358.4	911.2	934.2	934.2
1986	1.387	0.0	1.347	0.0	349.4	361.0	361.0	935.3	964.4	964.4
1987	1.598	0.0	1.512	0.0	349.5	363.7	363.7	958.2	994.5	994.5
1988	1.655	0.0	1.607	0.0	352.0	366.3	366.3	987.2	1024.7	1024.7
1989	1.765	0.0	1.716	0.0	351.9	369.0	369.0	1009.2	1054.8	1054.8
1990	1.857	0.0	1.808	0.0	354.4	371.6	371.6	1038.0	1084.9	1084.9
2000	2.818	0.0	2.777	1.148	367.8	401.5	401.5	1379.4	1497.4	1497.4
2010	4.146	2.616	4.087	2.586	380.9	418.4	439.5	1784.9	1949.0	2041.3
2020	5.536	4.171	5.483	4.171	396.4	435.7	483.2	2280.5	2491.5	2747.4

APPENDIX I. 3.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 2

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.084	0.084	0.084	0.084	335.2	335.2	335.8	682.4	682.4	682.8
1977	0.084	0.084	0.084	0.084	337.5	337.5	338.1	707.5	707.5	708.0
1978	0.095	0.095	1.543	0.095	339.7	339.7	340.5	732.4	732.4	733.2
1979	0.106	0.106	8.790	0.106	341.9	341.9	342.8	757.5	757.5	758.3
1980	0.109	0.109	3.099	0.109	344.1	344.1	345.2	782.6	782.6	783.5
1981	0.127	0.127	0.694	0.127	346.6	346.6	347.8	812.3	812.3	813.7
1982	0.144	0.144	0.824	0.144	349.2	349.2	350.5	842.0	842.0	843.8
1983	0.162	0.162	0.964	0.162	351.6	351.6	353.1	871.6	871.6	873.9
1984	1.181	0.181	0.981	0.181	350.0	354.1	355.7	891.2	901.0	904.1
1985	1.204	0.198	1.144	0.198	350.9	356.5	358.4	916.6	930.3	934.2
1986	1.284	0.218	1.253	0.218	351.6	358.9	361.0	941.1	959.5	964.4
1987	1.377	0.226	1.343	0.226	353.8	361.3	363.7	969.2	988.5	994.5
1988	1.482	0.237	1.447	0.237	354.4	363.9	366.3	993.5	1018.5	1024.7
1989	1.588	0.262	1.551	0.262	356.7	366.3	369.0	1021.6	1047.3	1054.8
1990	1.820	0.283	1.738	0.283	356.7	368.6	371.6	1043.6	1076.0	1084.9
2000	2.612	0.380	2.583	0.380	374.9	396.7	401.5	1400.7	1477.1	1497.4
2010	3.709	0.502	3.672	1.864	395.9	432.5	439.5	1844.7	2003.4	2041.3
2020	5.056	3.284	5.012	3.245	416.6	454.8	483.2	2379.7	2583.1	2747.4

APPENDIX I. 4.1: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 3
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	797.1	797.1	797.1	4923.4	4923.4	4923.4
1977	0.0	0.0	0.0	0.0	797.0	797.0	797.0	5056.9	5056.9	5056.9
1978	0.0	0.0	6.554	0.0	796.9	796.9	796.9	5190.3	5190.3	5190.3
1979	0.0	0.0	26.413	0.0	796.7	796.7	796.7	5323.7	5323.7	5323.7
1980	0.0	0.0	5.329	0.0	796.6	796.6	796.6	5457.2	5457.2	5457.2
1981	0.0	0.0	1.412	0.0	796.5	796.5	796.5	5611.7	5611.7	5611.7
1982	2.548	0.0	1.553	0.0	782.4	796.4	796.4	5650.0	5766.3	5766.3
1983	1.578	0.0	1.693	0.0	778.1	796.3	796.3	5766.3	5920.8	5920.8
1984	1.589	0.0	1.829	0.0	773.0	796.2	796.2	5873.0	6075.4	6075.4
1985	2.109	0.0	1.951	0.0	772.5	796.1	796.1	6022.6	6230.0	6230.0
1986	2.258	0.0	2.081	0.0	767.5	796.0	796.0	6124.1	6384.5	6384.5
1987	2.656	0.0	2.300	0.0	761.5	795.9	795.9	6218.2	6539.1	6539.1
1988	2.649	0.0	2.447	0.0	761.1	795.8	795.8	6361.3	6693.6	6693.6
1989	2.785	0.0	2.574	0.0	754.6	795.7	795.7	6446.2	6848.2	6848.2
1990	2.927	0.0	2.721	0.0	754.5	795.6	795.6	6592.1	7002.8	7002.8
2000	3.912	0.0	3.738	1.783	721.5	794.7	794.7	8047.6	8967.9	8567.9
2010	5.218	3.640	4.968	3.527	684.9	759.2	801.0	9543.4	10705.6	11359.4
2020	6.255	5.060	6.030	5.060	652.2	722.6	807.5	11211.3	12559.4	14187.5

APPENDIX I. 4.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 3

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.063	0.063	0.063	0.063	794.8	794.8	797.1	4899.7	4899.7	4923.4
1977	0.045	0.045	0.045	0.045	793.8	793.8	797.0	5026.8	5026.8	5056.9
1978	0.049	0.049	3.610	0.049	792.4	792.4	796.9	5152.2	5152.2	5190.3
1979	0.056	0.056	27.711	0.056	790.7	790.7	796.7	5276.0	5276.0	5323.7
1980	0.073	0.073	5.179	0.073	786.9	786.9	796.6	5386.9	5386.9	5457.2
1981	0.025	0.025	0.985	0.025	786.7	786.7	796.5	5538.5	5538.5	5611.7
1982	0.026	0.026	1.182	0.026	786.5	786.5	796.4	5690.1	5690.1	5766.3
1983	0.027	0.027	1.385	0.027	786.3	786.3	796.3	5841.8	5841.8	5920.8
1984	2.171	0.029	1.332	0.029	775.4	785.7	796.2	5901.8	5990.6	6075.4
1985	1.808	0.027	1.555	0.027	771.7	785.5	796.1	6019.8	6142.2	6230.0
1986	1.832	0.028	1.691	0.028	767.4	785.3	796.0	6131.3	6293.7	6384.5
1987	1.950	0.029	1.809	0.029	767.2	785.1	795.9	6279.1	6445.3	6539.1
1988	2.103	0.030	1.944	0.030	762.0	784.9	795.8	6379.7	6596.8	6693.6
1989	2.227	0.031	2.069	0.031	761.8	784.7	795.7	6526.4	6748.4	6848.2
1990	2.654	0.032	2.305	0.032	756.4	784.5	795.6	6621.9	6899.9	7002.8
2000	3.341	0.042	3.215	0.042	735.4	783.0	794.7	8235.6	8830.7	8967.9
2010	4.404	0.049	4.246	2.132	715.1	788.0	801.0	10038.6	11171.2	11359.4
2020	5.535	3.678	5.347	3.543	688.7	757.6	807.5	11946.2	13258.4	14187.5

APPENDIX I. 5.1: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 4
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	259.2	259.2	259.2	709.2	709.2	709.2
1977	0.0	0.0	0.0	0.0	261.5	261.5	261.5	731.0	731.0	731.0
1978	0.0	0.0	1.129	0.0	263.7	263.7	263.7	752.8	752.8	752.8
1979	0.0	0.0	4.191	0.0	265.9	265.9	265.9	774.6	774.6	774.6
1980	0.0	0.0	1.360	0.0	268.1	268.1	268.1	796.4	796.4	796.4
1981	0.0	0.0	0.363	0.0	270.8	270.8	270.8	828.3	828.3	828.3
1982	0.522	0.0	0.396	0.0	269.6	273.4	273.4	846.0	860.3	860.3
1983	0.490	0.0	0.448	0.0	270.5	276.1	276.1	872.4	892.2	892.2
1984	0.512	0.0	0.490	0.0	272.1	278.7	278.7	898.7	924.1	924.1
1985	0.561	0.0	0.536	0.0	274.6	281.4	281.4	929.1	956.1	956.1
1986	0.605	0.0	0.580	0.0	275.7	284.0	284.0	954.2	988.0	988.0
1987	0.658	0.0	0.651	0.0	276.7	286.7	286.7	978.8	1019.9	1019.9
1988	0.730	0.0	0.701	0.0	278.8	289.3	289.3	1007.2	1051.9	1051.9
1989	0.777	0.0	0.748	0.0	279.8	292.0	292.0	1031.4	1083.8	1083.8
1990	0.811	0.0	0.788	0.0	282.4	294.6	294.6	1061.9	1115.7	1115.7
2000	1.253	0.0	1.227	0.569	300.6	325.9	325.9	1435.8	1576.8	1576.8
2010	1.882	1.283	1.845	1.261	320.6	349.4	366.3	1612.9	2110.1	2226.4
2020	2.622	2.077	2.588	2.077	344.4	376.0	414.2	2539.2	2807.3	3128.9

APPENDIX I. 5.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 4

SERVICE: ACW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.183	0.183	0.183	0.183	255.3	255.3	255.2	688.9	688.9	709.2
1977	0.153	0.153	0.153	0.153	256.1	256.1	261.5	704.5	704.5	731.0
1978	0.164	0.164	0.765	0.164	257.0	257.0	263.7	720.0	720.0	752.8
1979	0.170	0.170	4.218	0.170	257.8	257.8	265.9	734.1	734.1	774.6
1980	0.185	0.185	1.344	0.185	258.8	258.8	268.1	749.4	749.4	796.4
1981	0.180	0.180	0.403	0.180	260.7	260.7	270.8	776.2	776.2	828.3
1982	0.185	0.185	0.453	0.185	262.7	262.7	273.4	802.8	802.8	860.3
1983	0.197	0.197	0.514	0.197	265.0	265.0	276.1	831.3	831.3	892.2
1984	0.628	0.200	0.513	0.200	264.2	266.9	278.7	847.4	857.3	924.1
1985	0.614	0.212	0.582	0.212	265.5	269.3	281.4	871.6	885.8	956.1
1986	0.645	0.224	0.631	0.224	266.9	271.6	284.0	895.8	914.2	988.0
1987	0.697	0.234	0.678	0.234	268.9	273.9	286.7	922.7	942.6	1019.9
1988	0.743	0.239	0.722	0.239	270.0	276.3	289.3	946.0	971.0	1051.9
1989	0.781	0.248	0.763	0.248	272.3	278.6	292.0	973.8	999.5	1083.8
1990	0.894	0.257	0.846	0.257	273.0	280.9	294.6	995.0	1027.9	1115.7
2000	1.286	0.394	1.269	0.394	290.0	304.8	325.9	1336.0	1412.4	1576.8
2010	1.840	0.574	1.820	1.169	306.8	331.8	366.3	1748.4	1906.4	2226.4
2020	2.540	1.931	2.514	1.906	325.0	350.6	414.2	2265.7	2461.6	3128.9

APPENDIX I. 6.1: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 5
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	130.2	130.2	130.2	179.5	179.5	179.5
1977	0.0	0.0	0.0	0.0	133.0	133.0	133.0	188.8	188.8	188.8
1978	0.0	0.0	0.323	0.0	135.8	135.8	135.8	198.1	198.1	198.1
1979	0.0	0.0	1.289	0.0	138.6	138.6	138.6	207.3	207.3	207.3
1980	0.0	0.0	0.352	0.0	141.4	141.4	141.4	216.6	216.6	216.6
1981	0.0	0.0	0.095	0.0	145.1	145.1	145.1	230.5	230.5	230.5
1982	0.151	0.0	0.105	0.0	147.0	148.8	148.8	241.2	244.4	244.4
1983	0.129	0.0	0.116	0.0	150.2	152.4	152.4	254.0	258.3	258.3
1984	0.142	0.0	0.131	0.0	153.1	156.1	156.1	266.4	272.2	272.2
1985	0.154	0.0	0.144	0.0	156.6	159.8	159.8	279.8	286.1	286.1
1986	0.167	0.0	0.157	0.0	159.5	163.4	163.4	292.0	300.0	300.0
1987	0.198	0.0	0.179	0.0	162.2	167.1	167.1	303.6	313.9	313.9
1988	0.203	0.0	0.193	0.0	165.7	170.8	170.8	317.0	327.8	327.8
1989	0.222	0.0	0.210	0.0	168.2	174.4	174.4	328.2	341.7	341.7
1990	0.234	0.0	0.225	0.0	171.6	178.1	178.1	341.4	355.6	355.6
2000	0.429	0.0	0.419	0.194	211.1	226.6	226.6	542.3	585.4	585.4
2010	0.781	0.523	0.768	0.513	259.8	281.2	293.8	842.8	916.9	960.5
2020	1.296	1.010	1.275	1.010	321.1	349.9	385.0	1296.7	1420.3	1570.2

APPENDIX I. 6.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 5

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.154	0.154	0.154	0.154	124.7	124.7	130.2	170.0	170.0	179.5
1977	0.106	0.106	0.106	0.106	125.1	125.1	133.0	174.8	174.8	188.8
1978	0.107	0.107	0.250	0.107	125.4	125.4	135.8	179.4	179.4	198.1
1979	0.126	0.126	1.169	0.126	124.6	124.6	138.6	181.9	181.9	207.3
1980	0.168	0.168	0.420	0.168	120.0	120.0	141.4	177.0	177.0	216.6
1981	0.082	0.082	0.131	0.082	122.8	122.8	145.1	188.0	188.0	230.5
1982	0.088	0.088	0.147	0.088	125.6	125.6	148.8	198.9	198.9	244.4
1983	0.098	0.098	0.168	0.098	128.4	128.4	152.4	209.8	209.8	258.3
1984	0.203	0.103	0.171	0.103	130.1	131.0	156.1	218.8	220.5	272.2
1985	0.202	0.112	0.193	0.112	132.3	133.6	159.8	228.5	231.1	286.1
1986	0.220	0.120	0.212	0.120	134.4	136.2	163.4	238.2	241.7	300.0
1987	0.235	0.134	0.231	0.134	136.8	138.6	167.1	248.5	252.1	313.9
1988	0.261	0.147	0.254	0.147	138.6	140.8	170.8	257.7	262.3	327.8
1989	0.285	0.163	0.278	0.163	139.4	141.8	174.4	264.5	269.6	341.7
1990	0.358	0.215	0.346	0.215	139.4	142.4	178.1	271.4	277.7	355.6
2000	0.447	0.203	0.441	0.203	170.8	177.4	226.6	431.9	450.1	585.4
2010	0.769	0.329	0.761	0.535	209.9	224.4	293.8	674.9	725.0	960.5
2020	1.235	0.962	1.228	0.951	259.4	278.5	385.0	1044.0	1126.1	1570.2

APPENDIX I. 7.1: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 6

SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	231.6	231.6	231.6	474.5	474.5	474.5
1977	0.0	0.0	0.0	0.0	231.4	231.4	231.4	487.2	487.2	487.2
1978	0.0	0.0	1.365	0.0	231.1	231.1	231.1	499.8	499.8	499.8
1979	0.0	0.0	5.175	0.0	230.9	230.9	230.9	512.5	512.5	512.5
1980	0.0	0.0	1.353	0.0	230.6	230.6	230.6	525.2	525.2	525.2
1981	0.0	0.0	0.357	0.0	230.5	230.5	230.5	539.2	539.2	539.2
1982	0.572	0.0	0.402	0.0	225.9	230.3	230.3	537.7	553.1	553.1
1983	0.489	0.0	0.439	0.0	224.4	230.1	230.1	546.5	567.1	567.1
1984	0.501	0.0	0.473	0.0	222.7	229.9	229.9	554.4	581.1	581.1
1985	0.534	0.0	0.505	0.0	222.5	229.8	229.8	567.8	595.1	595.1
1986	0.570	0.0	0.540	0.0	220.7	229.6	229.6	574.7	609.0	609.0
1987	0.667	0.0	0.602	0.0	218.7	229.4	229.4	580.7	623.0	623.0
1988	0.669	0.0	0.634	0.0	218.5	229.2	229.2	593.8	637.0	637.0
1989	0.705	0.0	0.669	0.0	216.3	229.1	229.1	598.5	651.0	651.0
1990	0.745	0.0	0.707	0.0	216.1	228.9	228.9	611.5	664.9	664.9
2000	0.981	0.0	0.950	0.421	205.3	227.9	227.9	720.7	835.2	835.2
2010	1.285	0.863	1.241	0.842	194.2	216.8	229.6	826.6	965.2	1043.3
2020	1.517	1.200	1.478	1.200	184.8	206.2	232.1	944.6	1100.8	1288.9

APPENDIX I. 7.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 6

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	231.6	231.6	231.6	474.5	474.5	474.5
1977	0.0	0.0	0.0	0.0	231.4	231.4	231.4	487.2	487.2	487.2
1978	0.0	0.0	0.772	0.0	231.1	231.1	231.1	499.8	499.8	499.8
1979	0.0	0.0	5.421	0.0	230.9	230.9	230.9	512.5	512.5	512.5
1980	0.0	0.0	1.308	0.0	230.6	230.6	230.6	525.2	525.2	525.2
1981	0.0	0.0	0.245	0.0	230.5	230.5	230.5	539.2	539.2	539.2
1982	0.0	0.0	0.294	0.0	230.3	230.3	230.3	553.1	553.1	553.1
1983	0.0	0.0	0.345	0.0	230.1	230.1	230.1	567.1	567.1	567.1
1984	0.491	0.0	0.340	0.0	226.7	229.9	229.9	569.2	581.1	581.1
1985	0.443	0.0	0.398	0.0	225.4	229.8	229.8	578.6	595.1	595.1
1986	0.459	0.0	0.434	0.0	223.9	229.6	229.6	587.1	609.0	609.0
1987	0.490	0.0	0.464	0.0	223.7	229.4	229.4	600.6	623.0	623.0
1988	0.527	0.0	0.500	0.0	222.0	229.2	229.2	608.1	637.0	637.0
1989	0.562	0.0	0.533	0.0	221.9	229.1	229.1	621.5	651.0	651.0
1990	0.657	0.0	0.595	0.0	220.0	228.9	228.9	627.8	664.9	664.9
2000	0.829	0.0	0.807	0.0	213.0	227.9	227.9	759.6	835.2	835.2
2010	1.073	0.0	1.046	0.484	206.9	229.6	229.6	904.6	1043.3	1043.3
2020	1.330	0.847	1.297	0.823	199.8	221.3	232.1	1053.9	1210.1	1288.9

APPENDIX I. 8.1: SUMMARY OF LOSSES
UNIT:CLUSTER NO. 7
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGC	NORMAL GC	DRAUGHT NOGO	DRAUGHT GC	POPULATION NOGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	194.0	194.0	194.0	366.8	366.8	366.8
1977	0.0	0.0	0.0	0.0	197.4	197.4	197.4	386.0	386.0	386.0
1978	0.0	0.0	0.495	0.0	200.8	200.8	200.8	405.1	405.1	405.1
1979	0.0	0.0	1.772	0.0	204.2	204.2	204.2	424.3	424.3	424.3
1980	0.0	0.0	0.708	0.0	207.6	207.6	207.6	443.4	443.4	443.4
1981	0.0	0.0	0.194	0.0	211.8	211.8	211.8	470.5	470.5	470.5
1982	0.258	0.0	0.212	0.0	214.0	216.0	216.0	486.1	497.6	497.6
1983	0.258	0.0	0.243	0.0	217.4	220.2	220.2	508.4	524.7	524.7
1984	0.284	0.0	0.274	0.0	220.9	224.5	224.5	530.5	551.8	551.8
1985	0.308	0.0	0.299	0.0	224.8	228.7	228.7	555.0	578.8	578.8
1986	0.342	0.0	0.332	0.0	228.2	232.9	232.9	576.1	605.9	605.9
1987	0.391	0.0	0.373	0.0	231.4	237.1	237.1	595.4	633.0	633.0
1988	0.416	0.0	0.405	0.0	235.3	241.4	241.4	618.4	660.1	660.1
1989	0.451	0.0	0.439	0.0	238.2	245.6	245.6	635.7	687.2	687.2
1990	0.469	0.0	0.460	0.0	242.3	249.8	249.8	660.9	714.2	714.2
2000	0.827	0.0	0.815	0.387	285.1	302.4	302.4	931.4	1084.0	1084.0
2010	1.374	0.968	1.359	0.958	335.6	357.6	371.2	1270.5	1513.0	1665.7
2020	2.048	1.765	2.037	1.765	395.5	422.9	458.0	1694.1	2057.5	2534.0

APPENDIX I. 8.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 7

SERVICE: NOW SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.282	0.282	0.282	0.282	187.6	187.6	194.0	336.2	336.2	366.8
1977	0.213	0.213	0.213	0.213	190.1	190.1	197.4	350.7	350.7	386.0
1978	0.243	0.243	0.460	0.243	191.9	191.9	200.8	364.2	364.2	405.1
1979	0.264	0.264	1.632	0.264	192.7	192.7	204.2	372.6	372.6	424.3
1980	0.295	0.295	0.744	0.295	193.5	193.5	207.6	383.3	383.3	443.4
1981	0.281	0.281	0.368	0.281	196.9	196.9	211.8	406.0	406.0	470.5
1982	0.313	0.313	0.419	0.313	199.7	199.7	216.0	424.3	424.3	497.6
1983	0.333	0.333	0.460	0.333	202.8	202.8	220.2	441.8	441.8	524.7
1984	0.503	0.342	0.468	0.342	204.7	205.9	224.5	454.9	461.8	551.8
1985	0.524	0.365	0.514	0.365	208.0	209.7	228.7	473.8	484.1	578.8
1986	0.555	0.384	0.549	0.384	210.9	213.1	232.9	490.1	503.4	605.9
1987	0.593	0.412	0.588	0.412	213.1	215.3	237.1	504.6	518.4	633.0
1988	0.615	0.415	0.608	0.415	216.7	219.5	241.4	524.7	543.6	660.1
1989	0.655	0.437	0.648	0.437	219.3	222.2	245.6	535.0	554.6	687.2
1990	0.704	0.453	0.690	0.453	221.6	225.3	249.8	550.5	576.4	714.2
2000	1.062	0.673	1.057	0.673	257.0	264.6	302.4	751.4	817.0	1084.0
2010	1.565	0.965	1.559	1.262	302.4	316.4	371.2	1045.8	1194.8	1665.7
2020	2.173	1.912	2.165	1.903	343.9	359.0	458.0	1269.0	1458.8	2534.0

APPENDIX I. 9.1: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 8
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGC	NORMAL GC	DRAUGHT NCGC	DRAUGHT GC	POPULATION NCGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGC	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	191.7	191.7	191.7	873.7	873.7	873.7
1977	0.0	0.0	0.0	0.0	193.2	193.2	193.2	921.5	921.5	921.5
1978	0.0	0.0	0.712	0.0	194.6	194.6	194.6	969.3	969.3	969.3
1979	0.0	0.0	2.417	0.0	196.1	196.1	196.1	1017.1	1017.1	1017.1
1980	0.0	0.0	0.963	0.0	197.5	197.5	197.5	1064.8	1064.8	1064.8
1981	0.0	0.0	0.259	0.0	199.1	199.1	199.1	1114.5	1114.5	1114.5
1982	0.341	0.0	0.288	0.0	198.6	200.6	200.6	1142.7	1164.1	1164.1
1983	0.326	0.0	0.310	0.0	199.7	202.2	202.2	1187.9	1213.7	1213.7
1984	0.359	0.0	0.344	0.0	200.5	203.7	203.7	1228.3	1263.3	1263.3
1985	0.387	0.0	0.374	0.0	201.7	205.3	205.3	1271.8	1313.0	1313.0
1986	0.401	0.0	0.394	0.0	202.8	206.9	206.9	1314.8	1362.6	1362.6
1987	0.439	0.0	0.423	0.0	204.0	208.4	208.4	1358.8	1412.2	1412.2
1988	0.479	0.0	0.460	0.0	204.8	210.0	210.0	1398.4	1461.8	1461.8
1989	0.499	0.0	0.486	0.0	206.0	211.5	211.5	1441.3	1511.5	1511.5
1990	0.521	0.0	0.509	0.0	207.0	213.1	213.1	1481.4	1561.1	1561.1
2000	0.829	0.0	0.814	0.388	217.4	230.0	230.0	1965.3	2162.6	2162.6
2010	1.206	0.845	1.186	0.836	228.6	242.4	250.5	2544.5	2803.6	2957.1
2020	1.614	1.340	1.592	1.340	239.0	254.7	273.0	3217.3	3569.0	3981.1

APPENDIX I. 9.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 8

SERVICE: NON SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.116	0.116	0.116	0.116	190.9	190.9	191.7	866.9	866.9	873.7
1977	0.090	0.090	0.090	0.090	192.3	192.3	193.2	914.4	914.4	921.5
1978	0.106	0.106	0.507	0.106	193.6	193.6	194.6	959.8	959.8	969.3
1979	0.118	0.118	2.437	0.118	194.7	194.7	196.1	1004.9	1004.9	1017.1
1980	0.142	0.142	0.990	0.142	195.6	195.6	197.5	1046.5	1046.5	1064.8
1981	0.122	0.122	0.288	0.122	197.5	197.5	199.1	1098.5	1098.5	1114.5
1982	0.123	0.123	0.322	0.123	199.0	199.0	200.6	1147.5	1147.5	1164.1
1983	0.124	0.124	0.354	0.124	200.6	200.6	202.2	1196.5	1196.5	1213.7
1984	0.416	0.126	0.361	0.126	200.6	202.1	203.7	1229.5	1245.5	1263.3
1985	0.403	0.128	0.392	0.128	201.6	203.7	205.3	1271.0	1294.5	1313.0
1986	0.433	0.130	0.422	0.130	202.8	205.2	206.9	1316.0	1343.5	1362.6
1987	0.464	0.137	0.454	0.137	203.5	206.4	208.4	1354.3	1388.7	1412.2
1988	0.491	0.139	0.480	0.139	204.8	208.0	210.0	1398.7	1437.6	1461.8
1989	0.522	0.141	0.510	0.141	205.9	209.5	211.5	1440.7	1486.5	1511.5
1990	0.557	0.143	0.542	0.143	207.0	211.1	213.1	1482.3	1535.3	1561.1
2000	0.842	0.199	0.832	0.199	218.7	227.1	230.0	1986.1	2116.6	2162.6
2010	1.206	0.271	1.194	0.738	231.5	245.9	250.5	2596.5	2868.6	2957.1
2020	1.616	1.220	1.601	1.208	243.8	258.6	273.0	3325.4	3655.7	3981.1

APPENDIX I.10.1: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 9
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGC	NORMAL GC	DRAUGHT NCGC	DRAUGHT GC	POPULATION NCGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGC	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	71.7	71.7	71.7	190.6	190.6	190.6
1977	0.0	0.0	0.0	0.0	74.4	74.4	74.4	202.2	202.2	202.2
1978	0.0	0.0	0.088	0.0	77.2	77.2	77.2	213.7	213.7	213.7
1979	0.0	0.0	0.350	0.0	80.0	80.0	80.0	225.3	225.3	225.3
1980	0.0	0.0	0.142	0.0	82.7	82.7	82.7	236.8	236.8	236.8
1981	0.0	0.0	0.043	0.0	87.0	87.0	87.0	257.9	257.9	257.9
1982	0.060	0.0	0.049	0.0	90.7	91.2	91.2	277.7	279.0	279.0
1983	0.064	0.0	0.060	0.0	94.8	95.4	95.4	298.0	300.2	300.2
1984	0.075	0.0	0.071	0.0	98.8	99.7	99.7	318.4	321.3	321.3
1985	0.087	0.0	0.083	0.0	102.8	103.9	103.9	338.6	342.4	342.4
1986	0.101	0.0	0.097	0.0	106.9	108.1	108.1	359.1	363.5	363.5
1987	0.114	0.0	0.112	0.0	110.8	112.4	112.4	379.0	384.6	384.6
1988	0.127	0.0	0.125	0.0	114.9	116.6	116.6	399.8	405.8	405.8
1989	0.152	0.0	0.147	0.0	118.7	120.9	120.9	419.0	426.9	426.9
1990	0.156	0.0	0.155	0.0	122.8	125.1	125.1	439.5	448.0	448.0
2000	0.410	0.0	0.407	0.188	181.5	190.7	190.7	804.2	849.1	849.1
2010	0.965	0.630	0.962	0.622	269.4	285.7	295.9	1447.3	1539.8	1599.2
2020	1.976	1.527	1.973	1.527	396.1	427.3	463.1	2534.7	2751.1	2992.6

APPENDIX I.10.2: SUMMARY OF LOSSES

UNIT:CLUSTER NO. 9

SERVICE: NEW SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.160	0.160	0.160	0.160	64.3	64.3	71.7	172.4	172.4	190.6
1977	0.098	0.098	0.098	0.098	65.3	65.3	74.4	178.7	178.7	202.2
1978	0.100	0.100	0.110	0.100	66.5	66.5	77.2	185.5	185.5	213.7
1979	0.111	0.111	0.174	0.111	67.5	67.5	80.0	191.7	191.7	225.3
1980	0.117	0.117	0.149	0.117	67.7	67.7	82.7	195.4	195.4	236.8
1981	0.128	0.128	0.135	0.128	71.1	71.1	87.0	212.2	212.2	257.9
1982	0.129	0.129	0.140	0.129	73.9	73.9	91.2	226.6	226.6	279.0
1983	0.134	0.134	0.149	0.134	76.4	76.4	95.4	240.5	240.5	300.2
1984	0.177	0.158	0.174	0.158	79.6	79.7	99.7	256.6	256.7	321.3
1985	0.186	0.164	0.185	0.164	82.8	82.9	103.9	272.7	273.0	342.4
1986	0.205	0.177	0.203	0.177	86.2	86.3	108.1	289.0	289.4	363.5
1987	0.225	0.194	0.225	0.194	89.5	89.7	112.4	305.0	305.8	384.6
1988	0.224	0.184	0.223	0.184	91.6	91.8	116.6	317.3	318.1	405.8
1989	0.246	0.205	0.245	0.205	94.8	95.0	120.9	333.3	334.2	426.9
1990	0.274	0.224	0.273	0.224	97.9	98.2	125.1	349.1	350.2	448.0
2000	0.535	0.401	0.538	0.401	138.8	140.4	190.7	604.6	612.8	845.1
2010	1.108	0.795	1.107	0.947	192.2	197.7	295.9	1020.3	1055.4	1599.2
2020	2.030	1.812	2.030	1.805	257.0	266.0	463.1	1653.4	1724.4	2992.6

APPENDIX I.11.1: SUMMARY OF LOSSES
UNIT:CLUSTER NO. 10
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGC	NORMAL GC	DRAUGHT NCGD	DRAUGHT GD	POPULATION NCGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGD	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	198.4	198.4	198.4	858.4	858.4	858.4
1977	0.0	0.0	0.0	0.0	199.8	199.8	199.8	900.1	900.1	900.1
1978	0.0	0.0	0.818	0.0	201.3	201.3	201.3	941.8	941.8	941.8
1979	0.0	0.0	2.995	0.0	202.8	202.8	202.8	983.5	983.5	983.5
1980	0.0	0.0	0.924	0.0	204.3	204.3	204.3	1025.2	1025.2	1025.2
1981	0.0	0.0	0.247	0.0	205.9	205.9	205.9	1070.4	1070.4	1070.4
1982	0.362	0.0	0.273	0.0	204.8	207.6	207.6	1095.1	1115.5	1115.5
1983	0.324	0.0	0.297	0.0	205.7	209.2	209.2	1133.5	1160.7	1160.7
1984	0.341	0.0	0.325	0.0	206.3	210.9	210.9	1170.3	1205.8	1205.8
1985	0.371	0.0	0.354	0.0	207.8	212.5	212.5	1213.4	1251.0	1251.0
1986	0.396	0.0	0.378	0.0	208.5	214.2	214.2	1248.9	1296.1	1296.1
1987	0.459	0.0	0.423	0.0	208.7	215.8	215.8	1281.1	1341.3	1341.3
1988	0.467	0.0	0.448	0.0	210.3	217.5	217.5	1324.5	1386.4	1386.4
1989	0.494	0.0	0.473	0.0	210.7	219.1	219.1	1356.7	1431.6	1431.6
1990	0.530	0.0	0.507	0.0	212.1	220.8	220.8	1397.9	1476.7	1476.7
2000	0.791	0.0	0.773	0.368	222.1	239.3	239.3	1864.6	2056.4	2056.4
2010	1.141	0.793	1.116	0.780	232.2	251.5	262.4	2418.8	2680.8	2829.9
2020	1.503	1.234	1.483	1.234	243.2	263.8	288.5	3105.9	3442.8	3847.8

APPENDIX I.11.2: SUMMARY OF LOSSES
UNIT:CLUSTER NO. 10
SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.137	0.137	0.137	0.137	197.0	197.0	198.4	850.4	850.4	858.4
1977	0.122	0.122	0.122	0.122	197.8	197.8	199.8	887.9	887.9	900.1
1978	0.132	0.132	0.568	0.132	198.8	198.8	201.3	926.2	926.2	941.8
1979	0.155	0.155	3.083	0.155	199.9	199.9	202.8	964.5	964.5	983.5
1980	0.163	0.163	0.950	0.163	200.8	200.8	204.3	1001.7	1001.7	1025.2
1981	0.169	0.169	0.318	0.169	201.9	201.9	205.9	1042.3	1042.3	1070.4
1982	0.185	0.185	0.365	0.185	202.8	202.8	207.6	1081.4	1081.4	1115.5
1983	0.202	0.202	0.413	0.202	204.2	204.2	209.2	1123.9	1123.9	1160.7
1984	0.506	0.227	0.430	0.227	203.1	205.0	210.9	1146.6	1161.7	1205.8
1985	0.479	0.220	0.456	0.220	203.7	206.3	212.5	1182.2	1203.4	1251.0
1986	0.505	0.240	0.496	0.240	204.5	207.9	214.2	1218.1	1246.6	1296.1
1987	0.537	0.248	0.524	0.248	205.7	209.2	215.8	1258.5	1287.9	1341.3
1988	0.582	0.273	0.568	0.273	204.7	209.1	217.5	1279.4	1317.7	1386.4
1989	0.611	0.281	0.597	0.281	206.3	210.7	219.1	1321.0	1360.3	1431.6
1990	0.672	0.290	0.640	0.290	206.4	211.9	220.8	1350.6	1400.4	1476.7
2000	0.944	0.435	0.933	0.435	213.3	222.9	239.3	1773.8	1882.3	2056.4
2010	1.280	0.595	1.266	0.935	220.4	235.7	262.4	2276.8	2487.7	2829.9
2020	1.673	1.388	1.656	1.375	228.3	243.3	288.5	2896.5	3146.9	3847.8

APPENDIX I.12.1: SUMMARY OF LOSSES
UNIT:REVERE (CL. 1)
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	44.0	44.0	44.0	56.8	56.8	56.8
1977	0.0	0.0	0.0	0.0	44.2	44.2	44.2	58.8	58.8	58.8
1978	0.0	0.0	0.211	0.0	44.4	44.4	44.4	60.8	60.8	60.8
1979	0.0	0.0	0.839	0.0	44.7	44.7	44.7	62.8	62.8	62.8
1980	0.0	0.0	0.184	0.0	44.9	44.9	44.9	64.8	64.8	64.8
1981	0.0	0.0	0.048	0.0	45.1	45.1	45.1	67.2	67.2	67.2
1982	0.065	0.0	0.054	0.0	44.5	45.4	45.4	68.0	69.6	69.6
1983	0.068	0.0	0.059	0.0	44.4	45.6	45.6	69.9	72.0	72.0
1984	0.069	0.0	0.064	0.0	44.4	45.9	45.9	71.6	74.3	74.3
1985	0.073	0.0	0.068	0.0	44.6	46.1	46.1	73.9	76.7	76.7
1986	0.078	0.0	0.073	0.0	44.5	46.3	46.3	75.5	79.1	79.1
1987	0.093	0.0	0.082	0.0	44.3	46.6	46.6	77.0	81.4	81.4
1988	0.093	0.0	0.087	0.0	44.6	46.8	46.8	79.3	83.8	83.8
1989	0.098	0.0	0.092	0.0	44.3	47.1	47.1	80.6	86.2	86.2
1990	0.104	0.0	0.097	0.0	44.6	47.3	47.3	82.8	88.5	88.5
2000	0.143	0.0	0.138	0.063	44.7	49.8	49.8	106.8	120.4	120.4
2010	0.198	0.134	0.190	0.130	44.5	49.9	53.0	133.5	151.5	161.6
2020	0.245	0.193	0.238	0.193	44.4	49.8	56.3	165.0	187.1	213.7

APPENDIX I.12.2: SUMMARY OF LOSSES

UNIT:REVERE (CL. 1)

SERVICE: NCW SERVED CNLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	44.0	44.0	44.0	56.8	56.8	56.8
1977	0.0	0.0	0.0	0.0	44.2	44.2	44.2	58.8	58.8	58.8
1978	0.0	0.0	0.116	0.0	44.4	44.4	44.4	60.8	60.8	60.8
1979	0.0	0.0	0.883	0.0	44.7	44.7	44.7	62.8	62.8	62.8
1980	0.0	0.0	0.178	0.0	44.9	44.9	44.9	64.8	64.8	64.8
1981	0.0	0.0	0.033	0.0	45.1	45.1	45.1	67.2	67.2	67.2
1982	0.0	0.0	0.040	0.0	45.4	45.4	45.4	69.6	69.6	69.6
1983	0.0	0.0	0.047	0.0	45.6	45.6	45.6	72.0	72.0	72.0
1984	0.073	0.0	0.046	0.0	45.2	45.9	45.9	73.1	74.3	74.3
1985	0.062	0.0	0.054	0.0	45.2	46.1	46.1	75.0	76.7	76.7
1986	0.063	0.0	0.059	0.0	45.1	46.3	46.3	76.8	79.1	79.1
1987	0.068	0.0	0.063	0.0	45.4	46.6	46.6	79.1	81.4	81.4
1988	0.073	0.0	0.068	0.0	45.3	46.8	46.8	80.8	83.8	83.8
1989	0.078	0.0	0.073	0.0	45.5	47.1	47.1	83.0	86.2	86.2
1990	0.093	0.0	0.082	0.0	45.4	47.3	47.3	84.6	88.5	88.5
2000	0.121	0.0	0.117	0.0	46.5	49.8	49.8	111.4	120.4	120.4
2010	0.165	0.0	0.160	0.076	47.6	53.0	53.0	143.6	161.6	161.6
2020	0.214	0.137	0.209	0.132	48.2	53.6	56.3	180.4	202.6	213.7

APPENDIX I.13.1: SUMMARY OF LOSSES
UNIT:BELMONT (CL. 2)
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGO	NORMAL GC	DRAUGHT NCGO	DRAUGHT GC	POPULATION NCGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGO	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	29.1	29.1	29.1	34.7	34.7	34.7
1977	0.0	0.0	0.0	0.0	29.3	29.3	29.3	36.1	36.1	36.1
1978	0.0	0.0	0.222	0.0	29.6	29.6	29.6	37.4	37.4	37.4
1979	0.0	0.0	0.777	0.0	29.8	29.8	29.8	38.7	38.7	38.7
1980	0.0	0.0	0.273	0.0	30.0	30.0	30.0	40.0	40.0	40.0
1981	0.0	0.0	0.073	0.0	30.2	30.2	30.2	41.6	41.6	41.6
1982	0.103	0.0	0.083	0.0	29.9	30.5	30.5	42.4	43.2	43.2
1983	0.097	0.0	0.091	0.0	29.9	30.7	30.7	43.7	44.8	44.8
1984	0.102	0.0	0.099	0.0	30.0	31.0	31.0	44.9	46.4	46.4
1985	0.109	0.0	0.106	0.0	30.2	31.2	31.2	46.4	48.0	48.0
1986	0.117	0.0	0.114	0.0	30.2	31.4	31.4	47.6	49.6	49.6
1987	0.126	0.0	0.127	0.0	30.1	31.7	31.7	48.7	51.2	51.2
1988	0.139	0.0	0.135	0.0	30.4	31.9	31.9	50.2	52.8	52.8
1989	0.148	0.0	0.143	0.0	30.3	32.2	32.2	51.2	54.4	54.4
1990	0.156	0.0	0.151	0.0	30.5	32.4	32.4	52.7	56.0	56.0
2000	0.230	0.0	0.226	0.093	31.4	35.0	35.0	70.1	78.2	78.2
2010	0.329	0.209	0.324	0.206	32.0	35.9	38.1	90.1	101.3	107.5
2020	0.426	0.322	0.421	0.322	32.7	36.7	41.5	114.5	128.7	145.7

APPENDIX I.13.2: SUMMARY OF LOSSES
UNIT:BELMONT (CL. 2)
SERVICE: NEW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	29.1	29.1	29.1	34.7	34.7	34.7
1977	0.0	0.0	0.0	0.0	29.3	29.3	29.3	36.1	36.1	36.1
1978	0.0	0.0	0.131	0.0	29.6	29.6	29.6	37.4	37.4	37.4
1979	0.0	0.0	0.806	0.0	29.8	29.8	29.8	38.7	38.7	38.7
1980	0.0	0.0	0.264	0.0	30.0	30.0	30.0	40.0	40.0	40.0
1981	0.0	0.0	0.050	0.0	30.2	30.2	30.2	41.6	41.6	41.6
1982	0.0	0.0	0.060	0.0	30.5	30.5	30.5	43.2	43.2	43.2
1983	0.0	0.0	0.070	0.0	30.7	30.7	30.7	44.8	44.8	44.8
1984	0.090	0.0	0.070	0.0	30.5	31.0	31.0	45.7	46.4	46.4
1985	0.089	0.0	0.083	0.0	30.6	31.2	31.2	47.1	48.0	48.0
1986	0.094	0.0	0.091	0.0	30.6	31.4	31.4	48.3	49.6	49.6
1987	0.101	0.0	0.097	0.0	30.9	31.7	31.7	49.9	51.2	51.2
1988	0.109	0.0	0.105	0.0	30.9	31.9	31.9	51.1	52.8	52.8
1989	0.116	0.0	0.112	0.0	31.1	32.2	32.2	52.6	54.4	54.4
1990	0.134	0.0	0.126	0.0	31.1	32.4	32.4	53.7	56.0	56.0
2000	0.192	0.0	0.189	0.0	32.6	35.0	35.0	72.8	78.2	78.2
2010	0.270	0.0	0.266	0.114	34.2	38.1	38.1	96.4	107.5	107.5
2020	0.364	0.218	0.360	0.215	35.5	39.5	41.5	124.4	138.6	145.7

APPENDIX I.14.1: SUMMARY OF LOSSES

UNIT:BOSTON (CL. 3)
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	627.8	627.8	627.8	3739.4	3739.4	3739.4
1977	0.0	0.0	0.0	0.0	627.7	627.7	627.7	3840.7	3840.7	3840.7
1978	0.0	0.0	5.840	0.0	627.7	627.7	627.7	3942.1	3942.1	3942.1
1979	0.0	0.0	23.749	0.0	627.6	627.6	627.6	4043.4	4043.4	4043.4
1980	0.0	0.0	4.518	0.0	627.5	627.5	627.5	4144.7	4144.7	4144.7
1981	0.0	0.0	1.194	0.0	627.5	627.5	627.5	4262.2	4262.2	4262.2
1982	2.233	0.0	1.320	0.0	615.1	627.4	627.4	4283.3	4379.7	4379.7
1983	1.694	0.0	1.434	0.0	611.3	627.4	627.4	4368.1	4497.2	4497.2
1984	1.684	0.0	1.543	0.0	607.0	627.3	627.3	4447.2	4614.7	4614.7
1985	1.801	0.0	1.652	0.0	606.9	627.2	627.2	4560.6	4732.2	4732.2
1986	1.912	0.0	1.756	0.0	602.1	627.2	627.2	4632.8	4849.7	4849.7
1987	2.289	0.0	1.954	0.0	596.7	627.1	627.1	4698.7	4967.2	4967.2
1988	2.251	0.0	2.072	0.0	596.7	627.0	627.0	4810.0	5084.7	5084.7
1989	2.358	0.0	2.171	0.0	590.9	627.0	627.0	4868.1	5202.2	5202.2
1990	2.499	0.0	2.304	0.0	590.8	626.9	626.9	4978.3	5319.7	5319.7
2000	3.307	0.0	3.150	1.490	562.1	626.3	626.3	6064.7	6831.9	6831.9
2010	4.383	3.050	4.158	2.948	530.2	594.8	631.1	7165.8	8128.8	8670.5
2020	5.220	4.214	5.019	4.214	501.5	562.5	636.1	8381.0	9499.5	10846.4

APPENDIX I.14.2: SUMMARY OF LOSSES

UNIT:BOSTON (CL. 3)

SERVICE: NOW SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	627.8	627.8	627.8	3739.4	3739.4	3739.4
1977	0.0	0.0	0.0	0.0	627.7	627.7	627.7	3840.7	3840.7	3840.7
1978	0.0	0.0	3.165	0.0	627.7	627.7	627.7	3942.1	3942.1	3942.1
1979	0.0	0.0	25.064	0.0	627.6	627.6	627.6	4043.4	4043.4	4043.4
1980	0.0	0.0	4.367	0.0	627.5	627.5	627.5	4144.7	4144.7	4144.7
1981	0.0	0.0	0.819	0.0	627.5	627.5	627.5	4262.2	4262.2	4262.2
1982	0.0	0.0	0.985	0.0	627.4	627.4	627.4	4379.7	4379.7	4379.7
1983	0.0	0.0	1.157	0.0	627.4	627.4	627.4	4497.2	4497.2	4497.2
1984	1.891	0.0	1.117	0.0	618.3	627.3	627.3	4540.3	4614.7	4614.7
1985	1.543	0.0	1.310	0.0	614.9	627.2	627.2	4628.4	4732.2	4732.2
1986	1.546	0.0	1.420	0.0	611.1	627.2	627.2	4710.9	4849.7	4849.7
1987	1.660	0.0	1.527	0.0	611.0	627.1	627.1	4825.2	4967.2	4967.2
1988	1.776	0.0	1.635	0.0	606.7	627.0	627.0	4900.8	5084.7	5084.7
1989	1.897	0.0	1.748	0.0	606.7	627.0	627.0	5014.2	5202.2	5202.2
1990	2.269	0.0	1.949	0.0	601.8	626.9	626.9	5082.6	5319.7	5319.7
2000	2.815	0.0	2.701	0.0	583.9	626.3	626.3	6325.4	6831.9	6831.9
2010	3.695	0.0	3.553	1.755	566.5	631.1	631.1	7707.5	8670.5	8670.5
2020	4.630	3.056	4.461	2.933	544.2	605.3	636.1	9164.0	10282.5	10846.4

APPENDIX I.15.1: SUMMARY OF LOSSES

UNIT: PEABODY (CL. 4)
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	51.4	51.4	51.4	128.6	128.6	128.6
1977	0.0	0.0	0.0	0.0	52.0	52.0	52.0	132.9	132.9	132.9
1978	0.0	0.0	0.161	0.0	52.6	52.6	52.6	137.2	137.2	137.2
1979	0.0	0.0	0.561	0.0	53.2	53.2	53.2	141.5	141.5	141.5
1980	0.0	0.0	0.210	0.0	53.8	53.8	53.8	145.8	145.8	145.8
1981	0.0	0.0	0.058	0.0	54.5	54.5	54.5	152.1	152.1	152.1
1982	0.072	0.0	0.055	0.0	54.9	55.2	55.2	157.3	158.4	158.4
1983	0.076	0.0	0.069	0.0	55.4	55.9	55.9	162.9	164.7	164.7
1984	0.081	0.0	0.077	0.0	55.8	56.6	56.6	168.3	171.0	171.0
1985	0.088	0.0	0.084	0.0	56.5	57.3	57.3	174.5	177.3	177.3
1986	0.097	0.0	0.093	0.0	56.9	58.0	58.0	179.6	183.6	183.6
1987	0.106	0.0	0.101	0.0	57.6	58.7	58.7	185.8	189.9	189.9
1988	0.115	0.0	0.110	0.0	57.9	59.4	59.4	190.7	196.2	196.2
1989	0.124	0.0	0.119	0.0	58.6	60.1	60.1	196.8	202.5	202.5
1990	0.120	0.0	0.120	0.0	59.2	60.8	60.8	202.9	208.8	208.8
2000	0.211	0.0	0.206	0.098	64.7	68.6	68.6	281.1	300.0	300.0
2010	0.327	0.222	0.321	0.219	70.2	75.1	78.2	379.4	408.2	426.7
2020	0.476	0.367	0.468	0.367	76.2	82.1	89.0	506.1	548.6	595.0

APPENDIX I.15.2: SUMMARY OF LOSSES

UNIT: PEABODY (CL. 4)

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	51.4	51.4	51.4	128.6	128.6	128.6
1977	0.0	0.0	0.0	0.0	52.0	52.0	52.0	132.9	132.9	132.9
1978	0.0	0.0	0.051	0.0	52.6	52.6	52.6	137.2	137.2	137.2
1979	0.0	0.0	0.577	0.0	53.2	53.2	53.2	141.5	141.5	141.5
1980	0.0	0.0	0.199	0.0	53.8	53.8	53.8	145.8	145.8	145.8
1981	0.0	0.0	0.042	0.0	54.5	54.5	54.5	152.1	152.1	152.1
1982	0.0	0.0	0.049	0.0	55.2	55.2	55.2	158.4	158.4	158.4
1983	0.0	0.0	0.056	0.0	55.9	55.9	55.9	164.7	164.7	164.7
1984	0.075	0.0	0.058	0.0	56.3	56.6	56.6	169.8	171.0	171.0
1985	0.069	0.0	0.066	0.0	56.8	57.3	57.3	175.4	177.3	177.3
1986	0.077	0.0	0.073	0.0	57.4	58.0	58.0	181.6	183.6	183.6
1987	0.086	0.0	0.082	0.0	57.9	58.7	58.7	186.9	189.9	189.9
1988	0.094	0.0	0.090	0.0	58.6	59.4	59.4	193.1	196.2	196.2
1989	0.091	0.0	0.091	0.0	59.2	60.1	60.1	199.3	202.5	202.5
1990	0.118	0.0	0.108	0.0	59.6	60.8	60.8	204.3	208.8	208.8
2000	0.185	0.0	0.181	0.0	65.9	68.6	68.6	286.9	300.0	300.0
2010	0.277	0.0	0.273	0.130	72.9	78.2	78.2	395.5	426.7	426.7
2020	0.411	0.273	0.405	0.268	79.9	85.5	89.0	533.1	573.3	595.0

APPENDIX I.16.1: SUMMARY OF LOSSES
UNIT:MEDFIELD (CL. 5)
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGC	NORMAL GC	DRAUGHT NCGC	DRAUGHT GC	POPULATION NCGC	POPULATION GC	POPULATION ENOUGH SUPPLY	TOTAL VALUE ACCRD NCGC	TOTAL VALUE ACCRD GC	TOTAL VALUE ACCRD ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	11.2	11.2	11.2	10.0	10.0	10.0
1977	0.0	0.0	0.0	0.0	11.5	11.5	11.5	10.5	10.5	10.5
1978	0.0	0.0	0.003	0.0	11.7	11.7	11.7	11.1	11.1	11.1
1979	0.0	0.0	0.011	0.0	12.0	12.0	12.0	11.6	11.6	11.6
1980	0.0	0.0	0.006	0.0	12.3	12.3	12.3	12.2	12.2	12.2
1981	0.0	0.0	0.002	0.0	12.6	12.6	12.6	13.0	13.0	13.0
1982	0.003	0.0	0.002	0.0	13.0	13.0	13.0	13.8	13.8	13.8
1983	0.004	0.0	0.003	0.0	13.3	13.3	13.3	14.5	14.6	14.6
1984	0.005	0.0	0.004	0.0	13.6	13.6	13.6	15.3	15.4	15.4
1985	0.004	0.0	0.004	0.0	14.0	14.0	14.0	16.1	16.2	16.2
1986	0.006	0.0	0.006	0.0	14.3	14.3	14.3	16.9	17.0	17.0
1987	0.007	0.0	0.007	0.0	14.6	14.7	14.7	17.7	17.8	17.8
1988	0.007	0.0	0.007	0.0	15.0	15.0	15.0	18.5	18.6	18.6
1989	0.008	0.0	0.008	0.0	15.3	15.4	15.4	19.3	19.4	19.4
1990	0.010	0.0	0.010	0.0	15.6	15.7	15.7	20.0	20.2	20.2
2000	0.024	0.0	0.024	0.012	19.7	20.1	20.1	32.5	33.2	33.2
2010	0.053	0.033	0.053	0.033	24.4	25.4	25.9	50.5	52.6	53.8
2020	0.093	0.071	0.093	0.071	30.0	31.5	33.4	76.6	80.7	85.9

APPENDIX I.16.2: SUMMARY OF LOSSES

UNIT:MEDFIELD (CL. 5)

SERVICE: NOW SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.009	0.009	0.009	0.009	11.1	11.1	11.2	9.9	9.9	10.0
1977	0.008	0.008	0.008	0.008	11.4	11.4	11.5	10.4	10.4	10.5
1978	0.009	0.009	0.009	0.009	11.6	11.6	11.7	11.0	11.0	11.1
1979	0.010	0.010	0.010	0.010	11.8	11.8	12.0	11.4	11.4	11.6
1980	0.011	0.011	0.011	0.011	12.1	12.1	12.3	12.0	12.0	12.2
1981	0.014	0.014	0.014	0.014	12.4	12.4	12.6	12.7	12.7	13.0
1982	0.017	0.017	0.017	0.017	12.6	12.6	13.0	13.4	13.4	13.8
1983	0.020	0.020	0.020	0.020	12.9	12.9	13.3	14.0	14.0	14.6
1984	0.020	0.020	0.020	0.020	13.1	13.1	13.6	14.7	14.7	15.4
1985	0.024	0.024	0.024	0.024	13.3	13.3	14.0	15.3	15.3	16.2
1986	0.025	0.025	0.025	0.025	13.6	13.6	14.3	16.1	16.1	17.0
1987	0.027	0.027	0.027	0.027	13.8	13.8	14.7	16.7	16.7	17.8
1988	0.029	0.029	0.029	0.029	14.2	14.2	15.0	17.4	17.4	18.6
1989	0.034	0.034	0.034	0.034	14.3	14.3	15.4	17.9	17.9	19.4
1990	0.031	0.031	0.031	0.031	14.6	14.6	15.7	18.7	18.7	20.2
2000	0.061	0.061	0.061	0.061	17.2	17.2	20.1	28.0	28.0	33.2
2010	0.099	0.099	0.099	0.099	19.4	19.4	25.9	39.4	39.4	53.8
2020	0.146	0.146	0.146	0.146	22.2	22.2	33.4	55.9	55.9	85.9

APPENDIX I.17.1: SUMMARY OF LOSSES
UNIT:MEDFORD (CL. 6)
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	64.0	64.0	64.0	109.5	109.5	109.5
1977	0.0	0.0	0.0	0.0	64.1	64.1	64.1	112.8	112.8	112.8
1978	0.0	0.0	0.382	0.0	64.2	64.2	64.2	116.1	116.1	116.1
1979	0.0	0.0	1.468	0.0	64.3	64.3	64.3	119.3	119.3	119.3
1980	0.0	0.0	0.373	0.0	64.3	64.3	64.3	122.6	122.6	122.6
1981	0.0	0.0	0.098	0.0	64.4	64.4	64.4	126.4	126.4	126.4
1982	0.160	0.0	0.111	0.0	63.2	64.5	64.5	126.6	130.1	130.1
1983	0.136	0.0	0.122	0.0	62.9	64.6	64.6	129.2	133.9	133.9
1984	0.140	0.0	0.132	0.0	62.6	64.7	64.7	131.6	137.7	137.7
1985	0.149	0.0	0.141	0.0	62.7	64.8	64.8	135.2	141.4	141.4
1986	0.160	0.0	0.151	0.0	62.3	64.9	64.9	137.3	145.2	145.2
1987	0.189	0.0	0.170	0.0	61.8	64.9	64.9	139.2	149.0	149.0
1988	0.190	0.0	0.180	0.0	61.9	65.0	65.0	142.7	152.7	152.7
1989	0.201	0.0	0.190	0.0	61.4	65.1	65.1	144.3	156.5	156.5
1990	0.213	0.0	0.202	0.0	61.4	65.2	65.2	147.8	160.3	160.3
2000	0.284	0.0	0.275	0.121	59.3	66.1	66.1	180.0	207.7	207.7
2010	0.376	0.252	0.363	0.245	56.7	63.6	67.5	212.7	247.4	266.8
2020	0.447	0.352	0.436	0.352	54.4	61.1	69.0	249.6	289.6	337.9

APPENDIX I.17.2: SUMMARY OF LOSSES
UNIT:MEDFORD (CL. 6)
SERVICE: NEW SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	64.0	64.0	64.0	109.5	109.5	109.5
1977	0.0	0.0	0.0	0.0	64.1	64.1	64.1	112.8	112.8	112.8
1978	0.0	0.0	0.215	0.0	64.2	64.2	64.2	116.1	116.1	116.1
1979	0.0	0.0	1.539	0.0	64.3	64.3	64.3	119.3	119.3	119.3
1980	0.0	0.0	0.360	0.0	64.3	64.3	64.3	122.6	122.6	122.6
1981	0.0	0.0	0.067	0.0	64.4	64.4	64.4	126.4	126.4	126.4
1982	0.0	0.0	0.081	0.0	64.5	64.5	64.5	130.1	130.1	130.1
1983	0.0	0.0	0.096	0.0	64.6	64.6	64.6	133.9	133.9	133.9
1984	0.139	0.0	0.094	0.0	63.8	64.7	64.7	135.0	137.7	137.7
1985	0.125	0.0	0.111	0.0	63.5	64.8	64.8	137.7	141.4	141.4
1986	0.129	0.0	0.122	0.0	63.2	64.9	64.9	140.1	145.2	145.2
1987	0.138	0.0	0.131	0.0	63.3	64.9	64.9	143.8	149.0	149.0
1988	0.149	0.0	0.141	0.0	62.9	65.0	65.0	146.0	152.7	152.7
1989	0.160	0.0	0.151	0.0	63.0	65.1	65.1	149.6	156.5	156.5
1990	0.198	0.0	0.170	0.0	62.6	65.2	65.2	151.6	160.3	160.3
2000	0.240	0.0	0.233	0.0	61.6	66.1	66.1	189.4	207.7	207.7
2010	0.314	0.0	0.306	0.141	60.6	67.5	67.5	232.2	266.8	266.8
2020	0.391	0.248	0.382	0.241	59.1	65.7	69.0	277.6	317.7	337.9

APPENDIX I.18.1: SUMMARY OF LOSSES
UNIT:RANDOLPH (CL.7)
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	30.8	30.8	30.8	65.5	65.5	65.5
1977	0.0	0.0	0.0	0.0	31.5	31.5	31.5	69.1	69.1	69.1
1978	0.0	0.0	0.015	0.0	32.1	32.1	32.1	72.6	72.6	72.6
1979	0.0	0.0	0.049	0.0	32.7	32.7	32.7	76.1	76.1	76.1
1980	0.0	0.0	0.035	0.0	33.3	33.3	33.3	79.6	79.6	79.6
1981	0.0	0.0	0.009	0.0	34.1	34.1	34.1	84.7	84.7	84.7
1982	0.010	0.0	0.010	0.0	34.9	34.9	34.9	89.6	89.7	89.7
1983	0.014	0.0	0.013	0.0	35.6	35.6	35.6	94.3	94.7	94.7
1984	0.014	0.0	0.014	0.0	36.3	36.4	36.4	99.3	99.7	99.7
1985	0.015	0.0	0.015	0.0	37.1	37.2	37.2	104.3	104.8	104.8
1986	0.019	0.0	0.019	0.0	37.9	37.9	37.9	109.3	109.8	109.8
1987	0.019	0.0	0.019	0.0	38.6	38.7	38.7	114.3	114.8	114.8
1988	0.025	0.0	0.024	0.0	39.3	39.5	39.5	118.7	119.8	119.8
1989	0.025	0.0	0.025	0.0	40.1	40.2	40.2	123.6	124.9	124.9
1990	0.026	0.0	0.026	0.0	40.9	41.0	41.0	128.6	129.9	129.9
2000	0.058	0.0	0.057	0.017	50.1	50.4	50.4	196.1	199.4	199.4
2010	0.126	0.071	0.126	0.071	61.4	62.2	62.6	292.9	303.0	307.9
2020	0.229	0.181	0.229	0.181	74.5	75.7	77.6	424.0	440.2	468.9

APPENDIX I.18.2: SUMMARY OF LOSSES

UNIT:RANDOLPH (CL.7)

SERVICE: NON SERVED ONLY

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.058	0.058	0.058	0.058	30.0	30.0	30.8	61.0	61.0	65.5
1977	0.046	0.046	0.046	0.046	30.7	30.7	31.5	64.2	64.2	69.1
1978	0.052	0.052	0.052	0.052	31.3	31.3	32.1	67.5	67.5	72.6
1979	0.052	0.052	0.052	0.052	31.9	31.9	32.7	70.8	70.8	76.1
1980	0.059	0.059	0.059	0.059	32.3	32.3	33.3	72.5	72.5	79.6
1981	0.060	0.060	0.060	0.060	33.0	33.0	34.1	77.1	77.1	84.7
1982	0.068	0.068	0.068	0.068	33.7	33.7	34.9	81.7	81.7	89.7
1983	0.068	0.068	0.068	0.068	34.5	34.5	35.6	86.3	86.3	94.7
1984	0.076	0.076	0.076	0.076	34.9	34.9	36.4	88.8	88.8	95.7
1985	0.077	0.077	0.077	0.077	35.7	35.7	37.2	93.3	93.3	104.8
1986	0.080	0.080	0.080	0.080	36.4	36.4	37.9	97.8	97.8	105.8
1987	0.089	0.089	0.089	0.089	37.2	37.2	38.7	102.3	102.3	114.8
1988	0.089	0.089	0.089	0.089	37.9	37.9	39.5	106.8	106.8	119.8
1989	0.098	0.098	0.098	0.098	38.3	38.3	40.2	108.4	108.4	124.9
1990	0.105	0.105	0.105	0.105	39.0	39.0	41.0	112.8	112.8	129.9
2000	0.172	0.172	0.172	0.172	45.3	45.3	50.4	146.3	146.3	199.4
2010	0.254	0.254	0.254	0.254	53.5	53.5	62.6	196.9	196.9	307.9
2020	0.348	0.348	0.348	0.348	62.6	62.6	77.6	251.7	251.7	468.9

APPENDIX I.19.1: SUMMARY OF LOSSES

UNIT:NATICK (CL. 8)
SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NOGO	NORMAL GO	DRAUGHT NOGO	DRAUGHT GO	POPULATION NOGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NOGO	TOTAL VALUE ADDED GO	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	32.3	32.3	32.3	177.2	177.2	177.2
1977	0.0	0.0	0.0	0.0	32.5	32.5	32.5	186.6	186.6	186.6
1978	0.0	0.0	0.045	0.0	32.7	32.7	32.7	196.1	196.1	196.1
1979	0.0	0.0	0.157	0.0	32.8	32.8	32.8	205.5	205.5	205.5
1980	0.0	0.0	0.090	0.0	33.0	33.0	33.0	214.9	214.9	214.9
1981	0.0	0.0	0.024	0.0	33.2	33.2	33.2	224.4	224.4	224.4
1982	0.028	0.0	0.025	0.0	33.4	33.5	33.5	233.3	233.9	233.9
1983	0.032	0.0	0.031	0.0	33.5	33.7	33.7	242.0	243.3	243.3
1984	0.031	0.0	0.031	0.0	33.7	33.9	33.9	251.5	252.8	252.8
1985	0.032	0.0	0.032	0.0	33.9	34.1	34.1	260.9	262.3	262.3
1986	0.039	0.0	0.037	0.0	34.2	34.3	34.3	270.3	271.7	271.7
1987	0.038	0.0	0.038	0.0	34.4	34.5	34.5	279.7	281.2	281.2
1988	0.046	0.0	0.044	0.0	34.6	34.7	34.7	289.1	290.6	290.6
1989	0.044	0.0	0.044	0.0	34.8	34.9	34.9	298.6	300.1	300.1
1990	0.045	0.0	0.045	0.0	35.0	35.1	35.1	308.0	309.6	309.6
2000	0.088	0.0	0.087	0.039	36.8	37.3	37.3	415.5	424.0	424.0
2010	0.143	0.095	0.141	0.095	38.5	39.6	40.0	552.0	563.9	571.6
2020	0.212	0.166	0.210	0.166	40.8	41.7	42.8	710.7	733.2	758.5

APPENDIX I.19.2: SUMMARY OF LOSSES
UNIT:NATICK (CL. 8)
SERVICE: NOW SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.116	0.116	0.116	0.116	31.4	31.4	32.3	170.4	170.4	177.2
1977	0.090	0.090	0.090	0.090	31.6	31.6	32.5	179.5	179.5	186.6
1978	0.106	0.106	0.106	0.106	31.6	31.6	32.7	186.6	186.6	196.1
1979	0.118	0.118	0.118	0.118	31.5	31.5	32.8	193.3	193.3	205.5
1980	0.142	0.142	0.142	0.142	31.1	31.1	33.0	196.6	196.6	214.9
1981	0.122	0.122	0.122	0.122	31.6	31.6	33.2	208.4	208.4	224.4
1982	0.123	0.123	0.123	0.123	31.8	31.8	33.5	217.2	217.2	233.9
1983	0.124	0.124	0.124	0.124	32.0	32.0	33.7	226.1	226.1	243.3
1984	0.126	0.126	0.126	0.126	32.2	32.2	33.9	234.9	234.9	252.8
1985	0.128	0.128	0.128	0.128	32.4	32.4	34.1	243.7	243.7	262.3
1986	0.130	0.130	0.130	0.130	32.6	32.6	34.3	252.6	252.6	271.7
1987	0.137	0.137	0.137	0.137	32.5	32.5	34.5	257.7	257.7	281.2
1988	0.139	0.139	0.139	0.139	32.7	32.7	34.7	266.4	266.4	290.6
1989	0.141	0.141	0.141	0.141	32.9	32.9	34.9	275.1	275.1	300.1
1990	0.143	0.143	0.143	0.143	33.1	33.1	35.1	283.8	283.8	309.6
2000	0.199	0.199	0.199	0.199	34.4	34.4	37.3	378.0	378.0	424.0
2010	0.271	0.271	0.271	0.271	35.3	35.3	40.0	483.1	483.1	571.6
2020	0.329	0.329	0.329	0.329	36.6	36.6	42.8	616.0	616.0	758.5

APPENDIX I.20.1: SUMMARY OF LOSSES
UNIT:NORTHBOROUGH (9)
SERVICE: ALL RECEIVERS

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	11.9	11.9	11.9	16.8	16.8	16.8
1977	0.0	0.0	0.0	0.0	12.4	12.4	12.4	17.8	17.8	17.8
1978	0.0	0.0	0.012	0.0	12.8	12.8	12.8	18.8	18.8	18.8
1979	0.0	0.0	0.046	0.0	13.3	13.3	13.3	19.8	19.8	19.8
1980	0.0	0.0	0.021	0.0	13.7	13.7	13.7	20.8	20.8	20.8
1981	0.0	0.0	0.006	0.0	14.4	14.4	14.4	22.7	22.7	22.7
1982	0.008	0.0	0.007	0.0	15.0	15.0	15.0	24.5	24.5	24.5
1983	0.009	0.0	0.008	0.0	15.6	15.7	15.7	26.3	26.4	26.4
1984	0.011	0.0	0.010	0.0	16.2	16.3	16.3	28.2	28.3	28.3
1985	0.013	0.0	0.012	0.0	16.8	17.0	17.0	29.9	30.1	30.1
1986	0.015	0.0	0.014	0.0	17.5	17.6	17.6	31.8	32.0	32.0
1987	0.017	0.0	0.017	0.0	18.1	18.3	18.3	33.5	33.8	33.8
1988	0.017	0.0	0.017	0.0	18.7	18.9	18.9	35.3	35.7	35.7
1989	0.021	0.0	0.020	0.0	19.4	19.6	19.6	37.2	37.5	37.5
1990	0.024	0.0	0.023	0.0	19.9	20.2	20.2	38.8	39.4	39.4
2000	0.061	0.0	0.060	0.027	28.6	29.8	29.8	71.2	74.2	74.2
2010	0.136	0.089	0.135	0.088	40.3	42.8	44.3	125.4	133.5	138.0
2020	0.261	0.199	0.261	0.199	56.3	60.7	65.8	216.2	233.0	253.0

APPENDIX I.20.2: SUMMARY OF LOSSES

UNIT:NORTHBOROUGH (9)

SERVICE: NOW SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.0	0.0	0.0	0.0	11.9	11.9	11.9	16.8	16.8	16.8
1977	0.0	0.0	0.0	0.0	12.4	12.4	12.4	17.8	17.8	17.8
1978	0.0	0.0	0.008	0.0	12.8	12.8	12.8	18.8	18.8	18.8
1979	0.0	0.0	0.048	0.0	13.3	13.3	13.3	19.8	19.8	19.8
1980	0.0	0.0	0.021	0.0	13.7	13.7	13.7	20.8	20.8	20.8
1981	0.0	0.0	0.004	0.0	14.4	14.4	14.4	22.7	22.7	22.7
1982	0.0	0.0	0.006	0.0	15.0	15.0	15.0	24.5	24.5	24.5
1983	0.0	0.0	0.007	0.0	15.7	15.7	15.7	26.4	26.4	26.4
1984	0.009	0.0	0.008	0.0	16.2	16.3	16.3	28.2	28.3	28.3
1985	0.010	0.0	0.009	0.0	16.9	17.0	17.0	30.0	30.1	30.1
1986	0.012	0.0	0.011	0.0	17.5	17.6	17.6	31.9	32.0	32.0
1987	0.012	0.0	0.012	0.0	18.2	18.3	18.3	33.7	33.8	33.8
1988	0.015	0.0	0.014	0.0	18.8	18.9	18.9	35.4	35.7	35.7
1989	0.017	0.0	0.017	0.0	19.4	19.6	19.6	37.3	37.5	37.5
1990	0.020	0.0	0.019	0.0	20.0	20.2	20.2	39.0	39.4	39.4
2000	0.050	0.0	0.049	0.0	29.0	29.8	29.8	72.3	74.2	74.2
2010	0.114	0.0	0.112	0.055	41.7	44.3	44.3	129.9	138.0	138.0
2020	0.223	0.146	0.223	0.143	59.1	63.2	65.8	226.9	242.8	253.0

APPENDIX I.21.1: SUMMARY OF LOSSES

UNIT: BRAINTREE (C.10)

SERVICE: ALL RECEIVERS

YEAR	CONCRETE LOSSES NORMAL NCGO	NORMAL GO	DRAUGHT NCGO	DRAUGHT GO	POPULATION NCGO	POPULATION GO	POPULATION ENOUGH SUPPLY	TOTAL VALUE ADDED NCGO	TOTAL VALUE ADDED GC	TOTAL VALUE ADDED ENOUGH SUPPLY
1976	0.0	0.0	0.0	0.0	38.7	38.7	38.7	176.7	176.7	176.7
1977	0.0	0.0	0.0	0.0	39.2	39.2	39.2	186.3	186.3	186.3
1978	0.0	0.0	0.049	0.0	39.8	39.8	39.8	195.8	195.8	195.8
1979	0.0	0.0	0.165	0.0	40.3	40.3	40.3	205.4	205.4	205.4
1980	0.0	0.0	0.091	0.0	40.9	40.9	40.9	215.0	215.0	215.0
1981	0.0	0.0	0.024	0.0	41.5	41.5	41.5	226.5	226.5	226.5
1982	0.030	0.0	0.025	0.0	42.0	42.1	42.1	237.0	238.1	238.1
1983	0.032	0.0	0.030	0.0	42.6	42.8	42.8	248.5	249.6	249.6
1984	0.037	0.0	0.036	0.0	43.3	43.4	43.4	260.0	261.2	261.2
1985	0.042	0.0	0.041	0.0	43.8	44.0	44.0	270.5	272.7	272.7
1986	0.045	0.0	0.047	0.0	44.4	44.7	44.7	281.9	284.3	284.3
1987	0.055	0.0	0.053	0.0	44.9	45.3	45.3	292.1	295.8	295.8
1988	0.054	0.0	0.054	0.0	45.5	45.9	45.9	303.5	307.3	307.3
1989	0.063	0.0	0.061	0.0	46.1	46.6	46.6	314.9	318.9	318.9
1990	0.070	0.0	0.067	0.0	46.5	47.2	47.2	324.4	330.4	330.4
2000	0.133	0.0	0.130	0.058	52.7	54.5	54.5	471.6	491.0	491.0
2010	0.224	0.1145	0.221	0.144	59.2	61.9	63.5	660.3	696.4	718.5
2020	0.335	0.2644	0.335	0.264	66.4	69.7	74.0	910.9	965.4	1035.5

APPENDIX I.21.2: SUMMARY OF LOSSES

UNIT:BRAINTREE (C.10)
SERVICE: NOW SERVED ONLY

	CONCRETE LOSSES				POPULATION			TOTAL VALUE ADDED		
	NORMAL		DRAUGHT				ENOUGH			ENOUGH
YEAR	NOGO	GO	NOGO	GO	NOGO	GO	SUPPLY	NOGO	GO	SUPPLY
1976	0.115	0.115	0.115	0.115	37.4	37.4	38.7	169.3	169.3	176.7
1977	0.099	0.099	0.099	0.099	37.3	37.3	39.2	174.6	174.6	186.3
1978	0.105	0.105	0.105	0.105	37.5	37.5	39.8	181.3	181.3	195.8
1979	0.125	0.125	0.125	0.125	37.6	37.6	40.3	187.5	187.5	205.4
1980	0.129	0.129	0.129	0.129	37.7	37.7	40.9	193.3	193.3	215.0
1981	0.131	0.131	0.131	0.131	37.8	37.8	41.5	200.4	200.4	226.5
1982	0.138	0.138	0.138	0.138	37.8	37.8	42.1	206.9	206.9	238.1
1983	0.146	0.146	0.146	0.146	38.4	38.4	42.8	217.0	217.0	249.6
1984	0.163	0.163	0.163	0.163	38.4	38.4	43.4	222.7	222.7	261.2
1985	0.153	0.153	0.153	0.153	38.9	38.9	44.0	232.6	232.6	272.7
1986	0.169	0.169	0.169	0.169	39.5	39.5	44.7	242.5	242.5	284.3
1987	0.164	0.164	0.164	0.164	40.1	40.1	45.3	252.5	252.5	295.8
1988	0.188	0.188	0.188	0.188	39.3	39.3	45.9	251.2	251.2	307.3
1989	0.191	0.191	0.191	0.191	39.8	39.8	46.6	260.7	260.7	318.9
1990	0.186	0.186	0.186	0.186	40.4	40.4	47.2	270.2	270.2	330.4
2000	0.270	0.270	0.270	0.270	43.0	43.0	54.5	363.8	363.8	491.0
2010	0.358	0.358	0.358	0.358	46.3	46.3	63.5	489.5	489.5	718.5
2020	0.471	0.471	0.471	0.471	50.8	50.8	74.0	669.2	669.2	1035.5

II. CONCRETE LOSSES OF POTENTIAL RECEIVERS

APPENDIX II.1.1.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL
ALTERNATIVE: NOGO
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.402	0.913	2.157	0.204	0.530	0.0	2.085	6.291
1983	0.461	1.042	2.508	0.237	0.600	0.0	0.584	5.432
1984	0.501	1.120	2.771	0.258	0.643	0.0	0.358	5.652
1985	0.543	1.204	2.960	0.280	0.688	0.0	0.386	6.061
1986	0.581	1.280	3.229	0.302	0.727	0.0	0.389	6.508
1987	0.636	1.406	3.623	0.336	0.793	0.0	0.764	7.558
1988	0.665	1.500	3.843	0.363	0.840	0.0	0.502	7.734
1989	0.723	1.579	4.148	0.386	0.880	0.0	0.488	8.204
1990	0.766	1.663	4.348	0.411	0.920	0.0	0.522	8.630
2000	1.173	2.359	6.759	0.701	1.318	0.0	0.474	12.784
2010	1.686	3.216	10.106	1.140	1.853	0.0	0.749	18.749
2020	2.249	4.105	13.898	1.713	2.465	0.0	0.866	25.296

APPENDIX II.1.1.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL
ALTERNATIVE: NOCC
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:DRAUGHT

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVALE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	C.C	C.C	0.0	C.C	0.0	0.0	C.C	0.0
1977	C.C	C.C	0.0	C.C	C.C	0.C	C.C	0.0
1978	C.7C4	1.6E2	3.486	C.350	C.98E	0.0	7.487	14.698
1979	1.795	4.1E9	8.672	C.89C	2.462	0.0	38.065	56.074
1980	1.495	3.410	7.C55	0.738	2.00E	0.C	C.23C	14.935
1981	C.407	0.915	1.892	C.2C1	0.534	0.0	0.034	3.983
1982	C.424	C.964	2.266	C.21E	C.55S	0.0	C.012	4.441
1983	0.461	1.042	2.508	C.237	C.60C	0.0	C.033	4.881
1984	C.5C1	1.120	2.771	C.25E	0.643	0.C	C.038	5.332
1985	C.543	1.2C4	2.96C	C.2EC	0.68E	0.C	C.065	5.74C
1986	C.581	1.2E0	3.229	C.3C2	C.727	C.C	C.05C	6.16S
1987	C.63E	1.4CE	3.623	0.33E	C.79S	0.C	0.077	6.871
1988	C.685	1.5C0	3.843	0.363	C.84C	0.0	C.105	7.337
1989	C.723	1.579	4.148	0.3E6	C.88C	0.0	C.077	7.793
1990	C.766	1.663	4.348	C.411	C.92C	0.0	0.127	8.235
2000	1.173	2.359	6.759	C.7C1	1.318	0.C	C.12E	12.436
2010	1.68E	3.21E	10.10E	1.14C	1.853	0.0	0.253	18.253
2020	2.249	4.1C5	13.898	1.713	2.465	0.C	0.425	24.855

APPENCIX II.1.2.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: NOGC
SERVICE: NCW SERVED CNLY
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.085	0.128	0.313	0.023	0.177	0.0	0.484	1.209
1977	0.093	0.141	0.361	0.026	0.192	0.0	0.127	0.940
1978	0.100	0.153	0.410	0.028	0.205	0.0	0.133	1.029
1979	0.103	0.162	0.461	0.031	0.215	0.0	0.173	1.144
1980	0.101	0.164	0.513	0.032	0.214	0.0	0.269	1.294
1981	0.107	0.174	0.556	0.035	0.222	0.0	0.075	1.170
1982	0.113	0.185	0.609	0.038	0.232	0.0	0.074	1.251
1983	0.120	0.198	0.665	0.041	0.243	0.0	0.090	1.358
1984	0.460	0.993	2.553	0.227	0.669	0.0	1.698	6.600
1985	0.519	1.124	2.931	0.260	0.738	0.0	0.593	6.165
1986	0.559	1.207	3.212	0.284	0.782	0.0	0.407	6.450
1987	0.600	1.290	3.434	0.309	0.825	0.0	0.438	8.899
1988	0.638	1.369	3.727	0.331	0.864	0.0	0.457	7.386
1989	0.677	1.453	3.953	0.355	0.905	0.0	0.506	7.850
1990	0.730	1.589	4.396	0.394	0.971	0.0	0.943	9.032
2000	1.117	2.246	6.656	0.672	1.347	0.0	0.430	12.469
2010	1.582	3.007	9.643	1.072	1.804	0.0	0.604	17.712
2020	2.020	3.836	13.520	1.624	2.334	0.0	0.803	24.138

APPENDIX II.1.2.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: NCOC
SERVICE: NOW SERVED ONLY
RUNOFF CONDITION:DROUGHT

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.085	0.128	0.313	0.023	0.177	0.0	0.484	1.209
1977	0.093	0.141	0.361	0.026	0.192	0.0	0.127	0.940
1978	0.532	1.241	2.687	0.287	0.807	0.0	3.502	9.026
1979	1.693	4.086	8.670	0.873	2.377	0.0	40.085	57.784
1980	1.352	3.286	7.044	0.715	1.925	0.0	0.459	14.825
1981	0.357	0.770	1.803	0.187	0.547	0.0	0.090	3.733
1982	0.418	0.901	2.104	0.199	0.617	0.0	0.099	4.337
1983	0.480	1.038	2.421	0.233	0.690	0.0	0.130	4.991
1984	0.460	0.993	2.553	0.227	0.665	0.0	0.099	5.001
1985	0.519	1.124	2.931	0.260	0.738	0.0	0.121	5.693
1986	0.559	1.207	3.212	0.284	0.782	0.0	0.137	6.180
1987	0.600	1.290	3.434	0.307	0.825	0.0	0.168	6.625
1988	0.638	1.369	3.727	0.331	0.864	0.0	0.160	7.088
1989	0.677	1.453	3.953	0.355	0.905	0.0	0.207	7.550
1990	0.739	1.589	4.396	0.394	0.971	0.0	0.291	8.380
2000	1.117	2.246	6.656	0.672	1.347	0.0	0.188	12.227
2010	1.582	3.007	9.643	1.072	1.804	0.0	0.302	17.410
2020	2.020	3.836	13.520	1.624	2.334	0.0	0.444	23.778

APPENDIX II.2.1.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL
ALTERNATIVE: GO
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM. INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	1.395	2.323	6.039	0.800	1.291	0.0	0.814	12.662
2020	2.233	3.489	10.123	1.411	2.022	0.0	0.839	20.118

APPENDIX II.2.1.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: GO
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:DRAUGHT

YEAR	INDUSTRIAL CITY:	EMER CITY:	RVAUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.685	1.219	2.511	0.353	0.662	0.0	0.248	5.678
2010	1.355	2.323	6.039	0.800	1.291	0.0	0.565	12.413
2020	2.233	3.485	10.123	1.411	2.022	0.0	0.839	20.119

APPENDIX II.2.2.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: GC
SERVICE: NCW SERVED CNLY
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVAUE	COMMERCE	SPRINKLNG	BUS.INVST	CCM.INVST	TOTAL
1976	0.085	0.128	0.313	0.023	0.177	0.0	0.484	1.209
1977	0.093	0.141	0.361	0.026	0.192	0.0	0.127	0.940
1978	0.100	0.153	0.410	0.028	0.205	0.0	0.133	1.029
1979	0.103	0.162	0.461	0.031	0.215	0.0	0.173	1.144
1980	0.101	0.164	0.513	0.032	0.214	0.0	0.269	1.294
1981	0.107	0.174	0.556	0.035	0.222	0.0	0.075	1.170
1982	0.113	0.185	0.609	0.038	0.232	0.0	0.074	1.251
1983	0.120	0.198	0.665	0.041	0.243	0.0	0.090	1.358
1984	0.125	0.208	0.717	0.044	0.252	0.0	0.095	1.442
1985	0.132	0.220	0.767	0.048	0.263	0.0	0.090	1.515
1986	0.139	0.231	0.818	0.051	0.273	0.0	0.102	1.614
1987	0.145	0.242	0.873	0.054	0.284	0.0	0.114	1.713
1988	0.150	0.251	0.920	0.057	0.290	0.0	0.113	1.781
1989	0.154	0.260	0.977	0.060	0.298	0.0	0.135	1.885
1990	0.162	0.269	1.034	0.064	0.305	0.0	0.198	2.032
2000	0.243	0.396	1.602	0.116	0.434	0.0	0.106	2.898
2010	0.346	0.599	2.439	0.196	0.603	0.0	0.161	4.304
2020	1.676	2.857	9.257	1.186	1.826	0.0	0.935	17.738

APPENDIX II.2.2.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: GO
SERVICE: NOW SERVED ONLY
RUNOFF CONDITION:DRAUGHT

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.085	0.128	0.313	0.023	0.177	0.0	0.484	1.209
1977	0.093	0.141	0.361	0.026	0.192	0.0	0.127	0.940
1978	0.100	0.153	0.410	0.028	0.205	0.0	0.133	1.029
1979	0.103	0.162	0.461	0.031	0.215	0.0	0.173	1.144
1980	0.101	0.164	0.513	0.032	0.214	0.0	0.269	1.294
1981	0.107	0.174	0.556	0.035	0.222	0.0	0.075	1.170
1982	0.113	0.185	0.609	0.038	0.232	0.0	0.074	1.251
1983	0.120	0.198	0.665	0.041	0.243	0.0	0.090	1.358
1984	0.125	0.208	0.717	0.044	0.252	0.0	0.095	1.442
1985	0.132	0.220	0.767	0.048	0.263	0.0	0.090	1.519
1986	0.139	0.231	0.818	0.051	0.273	0.0	0.102	1.614
1987	0.145	0.242	0.873	0.054	0.284	0.0	0.114	1.713
1988	0.150	0.251	0.920	0.057	0.290	0.0	0.113	1.781
1989	0.154	0.260	0.977	0.060	0.298	0.0	0.135	1.885
1990	0.162	0.269	1.034	0.064	0.305	0.0	0.198	2.032
2000	0.243	0.396	1.602	0.116	0.434	0.0	0.106	2.898
2010	1.105	1.873	5.214	0.654	1.231	0.0	0.454	10.533
2020	1.676	2.857	9.257	1.186	1.826	0.0	0.642	17.445

APPENDIX II.3.1.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: NET GC OVER NOGC
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	DOM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.402	0.913	2.157	0.204	0.530	0.0	2.085	6.291
1983	0.461	1.042	2.508	0.237	0.600	0.0	0.584	5.432
1984	0.501	1.120	2.771	0.258	0.643	0.0	0.358	5.652
1985	0.543	1.204	2.960	0.280	0.688	0.0	0.386	6.061
1986	0.581	1.280	3.229	0.302	0.727	0.0	0.389	6.508
1987	0.636	1.406	3.623	0.336	0.793	0.0	0.764	7.558
1988	0.685	1.500	3.843	0.363	0.840	0.0	0.502	7.734
1989	0.723	1.579	4.148	0.386	0.880	0.0	0.488	8.204
1990	0.766	1.663	4.348	0.411	0.920	0.0	0.522	8.630
2000	1.173	2.359	6.759	0.701	1.318	0.0	0.474	12.784
2010	0.250	0.853	4.067	0.340	0.562	0.0	-0.065	6.087
2020	0.015	0.616	3.776	0.302	0.443	0.0	0.027	5.179

APPENDIX II.3.1.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL
ALTERNATIVE: NET GO OVER NOGO
SERVICE: ALL RECEIVERS
RUNOFF CONDITION:DRAUGHT

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.704	1.682	3.486	0.350	0.988	0.0	7.487	14.698
1979	1.795	4.189	8.672	0.890	2.462	0.0	38.065	56.074
1980	1.495	3.410	7.055	0.738	2.008	0.0	0.230	14.935
1981	0.407	0.915	1.892	0.201	0.534	0.0	0.034	3.983
1982	0.424	0.964	2.266	0.216	0.559	0.0	0.012	4.441
1983	0.461	1.042	2.508	0.237	0.600	0.0	0.033	4.881
1984	0.501	1.120	2.771	0.258	0.643	0.0	0.038	5.332
1985	0.543	1.204	2.960	0.280	0.688	0.0	0.065	5.740
1986	0.581	1.280	3.229	0.302	0.727	0.0	0.050	6.169
1987	0.636	1.406	3.623	0.336	0.793	0.0	0.077	6.871
1988	0.685	1.500	3.843	0.363	0.840	0.0	0.105	7.337
1989	0.723	1.579	4.148	0.386	0.880	0.0	0.077	7.793
1990	0.766	1.663	4.348	0.411	0.920	0.0	0.127	8.235
2000	0.488	1.140	4.248	0.348	0.656	0.0	-0.122	6.758
2010	0.290	0.853	4.067	0.340	0.562	0.0	-0.312	5.840
2020	0.015	0.616	3.776	0.302	0.443	0.0	-0.414	4.738

APPENDIX II.3.2.1: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL

ALTERNATIVE: NET GC CVER ACGC
SERVICE: NCW SERVED CNLY
RUNOFF CONDITION:NORMAL

YEAR	INDUSTRIAL	CITY:EMER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	COM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	1.603	5.158
1984	0.335	0.785	1.836	0.182	0.417	0.0	0.503	4.646
1985	0.387	0.904	2.164	0.213	0.475	0.0	0.305	4.836
1986	0.420	0.976	2.394	0.233	0.509	0.0	0.325	5.182
1987	0.454	1.047	2.561	0.253	0.542	0.0	0.345	5.605
1988	0.487	1.118	2.807	0.273	0.574	0.0	0.371	5.965
1989	0.523	1.193	2.976	0.295	0.607	0.0	0.746	7.000
1990	0.577	1.319	3.362	0.330	0.666	0.0	0.324	9.571
2000	0.874	1.850	5.054	0.556	0.913	0.0	0.443	13.408
2010	1.236	2.448	7.204	0.877	1.200	0.0	-0.131	6.400
2020	0.344	0.979	4.262	0.438	0.508	0.0		

APPENDIX II.3.2.2: CONCRETE LOSSES OF POTENTIAL RECEIVERS, $63MILL
ALTERNATIVE: NET GC OVER NOGC
SERVICE: NEW SERVED ONLY
RUNOFF CONDITION:DRAUGHT

YEAR	INDUSTRIAL	CITY:FAER	CITY:RVNUE	COMMERCE	SPRINKLNG	BUS.INVST	DOM.INVST	TOTAL
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.433	1.088	2.277	0.229	0.602	0.0	3.369	7.997
1979	1.590	3.924	8.209	0.842	2.163	0.0	39.913	56.640
1980	1.291	3.122	6.530	0.683	1.714	0.0	0.190	13.531
1981	0.250	0.596	1.246	0.132	0.325	0.0	0.014	2.563
1982	0.304	0.716	1.495	0.161	0.385	0.0	0.025	3.087
1983	0.360	0.840	1.756	0.192	0.446	0.0	0.039	3.633
1984	0.335	0.785	1.836	0.182	0.417	0.0	0.004	3.559
1985	0.387	0.904	2.164	0.213	0.475	0.0	0.021	4.174
1986	0.420	0.976	2.394	0.233	0.509	0.0	0.035	4.566
1987	0.454	1.047	2.561	0.253	0.542	0.0	0.055	4.912
1988	0.487	1.118	2.807	0.273	0.574	0.0	0.047	5.308
1989	0.523	1.193	2.976	0.295	0.607	0.0	0.072	5.666
1990	0.577	1.319	3.362	0.330	0.666	0.0	0.093	6.348
2000	0.874	1.850	5.054	0.556	0.913	0.0	0.082	9.329
2010	0.476	1.134	4.429	0.418	0.572	0.0	-0.152	6.877
2020	0.344	0.979	4.262	0.438	0.508	0.0	-0.198	6.333

III. SAMPLE COMMUNITY PROFILES — A. SUPPLIERS

PROFILE: Athol

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	32.34 sq. mi.
	CHARACTER: Industrial/Residential	res. 4.0%; indus. 0.4%; vacant 87.8% public lands 3.0%
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1965	11,989
	AGE COMPOSITION	50.4% 20-64
	RACIAL COMPOSITION White; Negro; Other	99.3%; .6%; .1%
	Foreign Stock: (48.9% Canad.; 9.8% Ital.; 8.8% Russ.; 8.2% U.K.; 8.0% Lith.)	40.1%
	GROWTH TRENDS 1950-1960:	.7% incr.; net out-migration 1,046
	1955-1965:	1.6% decr.; net out-migration 1,234
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1967	$14,526,939
	TOTAL REVENUES, 1967	$ 1,[illegible]97,963
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	99
	Wholesale (7 firms) 1968 Payroll:	$339,000
	Retail (92 firms) 1963 Sales Per Capita:	$ 1,311
5. HOUSING	NEW UNITS BUILT, 1960-1970	162
	EXISTING UNITS, 1970	3,866
	VACANCY RATE, 1960	4.8%
6. EDUCATION	PRESENT ATTENDANCE, K-12 (1969)	2514
	PRESENT CLASSROOM SPACE, K-12 (1971)	51 classrooms
	TEACHERS CURRENTLY EMPLOYED (1969-1970)	48
	PUPIL-TEACHER RATIO: Elementary; Secondary	U
	TEACHER SALARY RANGE (1968-1969)	$5,750 - $$9,516
	COST PER PUPIL	$448
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	Ample

Unavailable data at this level of detail
N/A=not applicable

PROFILE: Athol

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	186.34 acres
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	0
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS	U.S.#20; Mass. #32,#2,#24
	AIR	Orange Municipal Airport
	RAIL	Boston & Maine RR (freight)
	BUS	Local bus franchises
	TRUCK	Local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	Athol Water Dept.: ground & Surface sources
	PRESENT GARBAGE COLLECTION SYSTEM	Combined garbage & refuse weekly
	PRESENT RESIDENTIAL INSURANCE RATE	N/A
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	N/A
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	1 (Planning Board)
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	2
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	0
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Athol

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968 (18 firms):	$ 127,000
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll, 1966 (230 firms)	$22,953,000
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 5,394
	PRESENT TAX REVENUE, 1967	$1,597,963
	PRESENT REGIONAL INCOME: 1959 Median Family Income, Worcester County	$ 5,977
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960 Private Government Self-Employed Unpaid Family Workers	3,902 379 310 15
	PRESENT UNEMPLOYMENT (1972 regional)	7.4% (Athol Labor Area)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	230
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: Erving

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	14.04 sq. mi.
	CHARACTER:	Industrial/Residential
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	1,260; 90/sq. mi.
	AGE COMPOSITION	49.2% 20-64
	RACIAL COMPOSITION	U
	White:	
	Foreign Stock:	
	GROWTH TRENDS	
	1950-1960:	3.8% decrease; net out-migration 147
	1955-1965:	2.3% decrease; net out-migration 144
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION,1970	$9,972,611
	TOTAL REVENUES 1970	$ 398,904
	ASSESSMENTS IN PROJECT AREA	U
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	10
	TOTAL ANNUAL PAYROLL, 1968	$75,068
5. HOUSING	NEW UNITS BUILT,1960-1970	19
	EXISTING UNITS,	U
	VACANCY RATE,	U
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private	353; 4
	PRESENT CLASSROOM SPACE, K-6	10
	TEACHERS CURRENTLY EMPLOYED	11
	PUPIL-TEACHER RATIO	15.2
	TEACHER SALARY RANGE	$6500-$11,000
	COST PER PUPIL	$741
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	Ample

U=unobtainable data at this level of detail
N/A=not applicable

PROFILE: Erving

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	U
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	0
9. TRANSPORTATION	MAJOR ARTERIES	Rtes. 2 & 63
	AIR	0
	RAIL	Boston & Maine RR (freight)
	BUS, TRUCK	Local franchises: Englander, Western Mass.
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM :	None in Erving Center; Ervingside: Millers Falls Water District
	PRESENT GARBAGE COLLECTION SYSTEM	Combined garbage & refuse weekly
	PRESENT RESIDENTIAL INSURANCE RATE	N/A
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	N/A
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	1 (Planning Board)
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	0
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	0
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Erving

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll,	U
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll	U
17. REAL INCOME	MEDIAN FAMILY INCOME,	U
	PRESENT TAX REVENUE, 1970	$398,904
	TOTAL ANNUAL PAYROLL	$8,542,022
	REGIONAL INCOME: 1959 Median Family Income, Franklin County	$5,455
18. EMPLOYMENT	PRESENT EMPLOYMENT,	U
	PRESENT UNEMPLOYMENT (1972 regional)	7.4%
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	23
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: **Greenfield**

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	21.47 sq. mi.
	CHARACTER: Industrial/Residential	22.6% developed; 2.2% cultivated; 51.1% wooded; 22.3% other open
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	18,084; 842/sq. mi.
	AGE COMPOSITION, 1960	64.3% 20-64 yrs.
	RACIAL COMPOSITION	
	White:	99.3%
	Foreign Stock: (26.2% Canadian; 21.5% Polish; 10.1% U.K.; 9.8% Irish; 7.2% German)	28.1%
	GROWTH TRENDS	
	1950-1960:	2.0% increase; net out-migration 1,323
	1955-1965:	1.1% increase; net out-migration 959
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1969	$83,858,835
	TOTAL REVENUES, 1964	$ 4,025,223
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS	
	Wholesale, 1968; Payroll	122; $1,099,049
	Retail, 1967; Sales Per Capita	217; $2,743
5. HOUSING	NEW UNITS BUILT, 1960-1970	574
	EXISTING UNITS, 1960	5,179
	VACANCY RATE, 1960	4.4%
6. EDUCATION	PRESENT ATTENDANCE, K-12 (1969)	3,589
	PRESENT CLASSROOM SPACE, K-12	162 classrooms
	TEACHERS CURRENTLY EMPLOYED (1969-1970)	177
	PUPIL-TEACHER RATIO: Elementary; Secondary (1969-1970)	19.9; 15.7
	TEACHER SALARY RANGE	$6,700 - $11,800
	COST PER PUPIL (1968-1969)	$659
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	Ample

N/A=not applicable

PROFILE: Greenfield

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	U
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	0
9. TRANSPORTATION	MAJOR ARTERIES, HIGHWAY	I-91, U.S. #5, Mass. #2, #10
	AIR	None
	RAIL	Boston & Maine RR (freight)
	BUS, TRUCK	Local franchises offering local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	Greenfield Water Department
	PRESENT GARBAGE COLLECTION SYSTEM	Combined garbage & refuse weekly
	PRESENT RESIDENTIAL INSURANCE RATE	N/A
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	N/A
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	1(Planning Board)
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	0
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	0
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Greenfield

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968	$1,503,629
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll	$35,918,547
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$5,692
	PRESENT TAX REVENUE, 1969	$4,025,223
	REGIONAL INCOME: 1959 Median Family Income, Franklin County	$5,455
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960 Private Government Self-Employed Unpaid Family Workers	5,345 797 596 3[illegible]
	PRESENT UNEMPLOYMENT (1972 regional)	9.8% (Greenfield Labor Area)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	469
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

TOWN: Orange

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	35.03 sq. mi.
	CHARACTER:	Industrial/Residential
	TOTAL ACREAGE TAKEN FOR PROJECT:	36 (2 road & pipeline; 34 dam)
	USE IN PROJECT AREA:	Forested open space
2. POPULATION	TOTAL,1970; DENSITY	6,104; 174/sq. mi.
	AGE COMPOSITION:	48.0% 20-64 yrs.
	RACIAL COMPOSITION: White; Negro; Other Foreign Stock	 100% 25.6%
	GROWTH TRENDS 1950-1960: 1955-1965:	 4.4% incr.; net out-migration 380 0.7% incr.; net out-migration 371
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION,1970	$12,938,820
	TOTAL REVENUES, 1970	$ 1,166,293
	ASSESSMENTS IN PROJECT AREA	U
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale) Wholesale (5 firms) 1968 Payroll: Retail (48 firms) 1968 Payroll	53 $ 98,092 $917,690
5. HOUSING	NEW UNITS BUILT,1960-1970	61
	EXISTING UNITS, 1970	1,417
	VACANCY RATE,1960	6.2%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1969-1970)	1,520; 75
	PRESENT CLASSROOM SPACE, K-12 (1971)	80 classrooms (incl. regional H.S.)
	TEACHERS CURRENTLY EMPLOYED (1969-1970)	32
	PUPIL-TEACHER RATIO: Elementary; Secondary	25.2; U
	TEACHER SALARY RANGE, (1971-1972)	$6,750 - $11,300
	COST PER PUPIL (1969-1970)	$686
	PRESENT BUSING	None in Project Area
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	Ample

U = Unobtainable data at this level of detail
N/A = not applicable

PROFILE: Orange

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	10 acres
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	0
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS	U.S.#202; Mass.#122,2,2A,78
	AIR	Municipal Airport
	RAIL	Boston & Maine RR (freight)
	BUS	Local franchises
	TRUCK	Local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	Orange Water Dept. - ground & surface sources
	PRESENT GARBAGE COLLECTION SYSTEM	Combined garbage & refuse weekly
	PRESENT RESIDENTIAL INSURANCE RATE	N/A
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	N/A
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	2 (Millers River Watershed Assoc.; Planning Board)
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	3
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	1
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

TOWN: **Orange**

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968 (12 firms):	$ 144,439
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll, 1968 (107 firms)	$6,463,846
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 5,355
	PRESENT TAX REVENUE , 1970	$1,166,293
	REGIONAL INCOME 1959 Median Family Income, Franklin County	$ 5,455
18. EMPLOYMENT	PRESENT EMPLOYMENT	U
	PRESENT UNEMPLOYMENT (1972 regional)	7.4% (Athol Labor Area)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS, 1968	107
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

best copy available

PROFILE: **Royalston**

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	41.99 sq. mi.
	CHARACTER:	Residential/Agricultural
	TOTAL ACREAGE TAKEN FOR PROJECT:	895 (4 pipeline; 891 dam)
	USE IN PROJECT AREA:	Open space; limited recreation; 3 light-duty rights of way
2. POPULATION	TOTAL, 1970; DENSITY	809; 19/sq. mi.
	AGE COMPOSITION:	47.8% 20-64 yrs.
	RACIAL COMPOSITION White; Negro; Other Foreign Stock:	U
	GROWTH TRENDS 1950-1960: 1955-1965:	 4.5% decr.; net out-migration 172 12.9% decr.; net out-migration 209
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1970	$1,272,064
	TOTAL REVENUES, 1970	$ 139,927
	ASSESSMENTS IN PROJECT AREA	U
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS, 1968	2 (grocery store & restaurant)
5. HOUSING	NEW UNITS BUILT, 1960-1970	10
	EXISTING UNITS	U
	VACANCY RATE	U
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1969)	217; 3
	PRESENT CLASSROOM SPACE, K-6	6 classrooms
	TEACHERS CURRENTLY EMPLOYED, 1969-1970	5
	PUPIL-TEACHER RATIO: Elementary; Secondary (1969-1970)	21.8; N/A
	TEACHER SALARY RANGE	$7,000 - $11,200
	COST PER PUPIL	$687
	PRESENT BUSING	U
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	Ample

Unascertainable data at this level of detail
N/A=not applicable

PROFILE: Royalston

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	U Royalston Falls P.R. Birch Hill R. State Forests
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	0
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS In Project Area	Mass. #32,#68 Deland Rd.; Old Tpke. Rd., Winchendon Rd.
	RAIL	Boston & Maine RR (freight)
	BUS	None
	TRUCK	Local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	None
	PRESENT GARBAGE COLLECTION SYSTEM	None
	PRESENT RESIDENTIAL INSURANCE RATE	N/A
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	N/A
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	1 (Planning Board)
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	2
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	1
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: **Royalston**

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll	U
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll	U
17. REAL INCOME	MEDIAN FAMILY INCOME,	U
	PRESENT TAX REVENUE , 1970	$139,927
	REGIONAL INCOME 1959 Median Family Income, Worcester County	$ 5,977
18. EMPLOYMENT	PRESENT EMPLOYMENT,	U
	PRESENT UNEMPLOYMENT (1972 regional)	7.4% (Athol Labor Area)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	2
	PRESENT VALUE ADDED, MANUFACTURES	No manufactures
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	37.19 sq. mi.
	CHARACTER:	Rural/residential; 135 acres devel.
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	492; seasonal 810; 13/sq. mi.
	AGE COMPOSITION	51.4% 20-64 yrs.
	RACIAL COMPOSITION	U
	White:	
	Foreign Stock:	
	GROWTH TRENDS	
	1950-1960:	.7% decrease; net out-migration 21
	1955-1965:	8% decrease; net out-migration 53
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1970	$1,492,243
	TOTAL REVENUES, 1970	$ 104,457
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	U
5. HOUSING	NEW UNITS BUILT, 1960-1970	24
	EXISTING UNITS	U
	VACANCY RATE	U
6. EDUCATION	PRESENT ATTENDANCE, K-12 (1969)	92
	PRESENT CLASSROOM SPACE, K-12	4 classrooms
	TEACHERS CURRENTLY EMPLOYED (1969-1970)	3
	PUPIL-TEACHER RATIO: Elementary; Secondary (1969-1970)	16.0; --
	TEACHER SALARY RANGE	$6500-$11,670
	COST PER PUPIL (1969-1970)	$891
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	Ample

U=unobtainable data at this level of detail
N/A=not applicable

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS Woodland Public-Owned State Park & Forest Other Open Land	 22,500 acres 10,250 acres 1,200 acres ±
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	0
9. TRANSPORTATION	MAJOR ARTERIES, HIGHWAY	Mass. #78
	AIR	None
	RAIL	None
	BUS	None
	TRUCK	Local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	Neither
	PRESENT GARBAGE COLLECTION SYSTEM	None
	PRESENT RESIDENTIAL INSURANCE RATE	N/A
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	N/A
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY CONESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	0
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	0
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	0
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Warwick

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll,	U
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll	U
17. REAL INCOME	MEDIAN FAMILY INCOME	U
	PRESENT TAX REVENUE, 1970	$104,457
	PRESENT REGIONAL INCOME 1959 Median Family Income, Franklin County	$5,455
... EMPLOYMENT	PRESENT EMPLOYMENT	U
	PRESENT UNEMPLOYMENT (1972 regional)	7.4% (Athol Labor Area)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	3
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: Winchendon

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	42.53 sq. mi.
	CHARACTER:	Industrial/Residential
	TOTAL ACREAGE TAKEN FOR PROJECT:	172 (7 easements; 165 dam)
	USE IN PROJECT AREA:	Rural; forested open space
2. POPULATION	TOTAL, 1970; DENSITY	6,635; 156/sq. mi.
	AGE COMPOSITION	49.6% 20-64 yrs.
	RACIAL COMPOSITION White; Negro; Other	100%
	Foreign Stock:	34.0%
	GROWTH TRENDS 1950-1960:	5.3% decr.; net out-migration 1,014
	1955-1965:	0.3% decr.; net out-migration 686
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION,1970	$12,777,436
	TOTAL REVENUES, 1970	$ 1,418,295
	ASSESSMENTS IN PROJECT AREA	U
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale) Wholesale (3 firms) 1968 Payroll Retail (71 firms) Per Capital Sales	74 $ 48,483 $9,307,000
5. HOUSING	NEW UNITS BUILT,1960-1970	85
	EXISTING UNITS, 1970	1,413
	VACANCY RATE, 1960	4.3%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1969-1970)	1,620; 114
	PRESENT CLASSROOM SPACE, K-12	72 classrooms
	TEACHERS CURRENTLY EMPLOYED (1969-1970)	77
	PUPIL-TEACHER RATIO: Elementary; Secondary	24.6; 17.2
	TEACHER SALARY RANGE	$6,725; $12,675
	COST PER PUPIL	$768
	PRESENT BUSING	None in Project Area
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	Ample

Unavailable data at this level of detail
N/A not available

PROFILE: Winchendon

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS Developed: Undeveloped: Dept. of Conservation: State-Owned: 1990 RECREATION PLAN	177.5 acres 206.3 acres 4.6 acres 210.6 acres U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	0
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS AIR RAIL BUS TRUCK	U.S.202, Mass. 140 None Boston & Maine RR (freight) Local franchises Local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM PRESENT GARBAGE COLLECTION SYSTEM PRESENT RESIDENTIAL INSURANCE RATE	Winchendon Water Dept.- ground & surface sources Weekly N/A
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	N/A
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	2 (Planning Board; Conservation Comm.)
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	1
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST. APPLICATIONS TO M.D.C. FOR SERVICE	1 N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: **Winchendon**

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll	U
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll	U
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 5,330
	PRESENT TAX REVENUE, 1970	$1,418,295
	REGIONAL INCOME 1959 Median Family Income, Worcester County	$ 5,977
18. EMPLOYMENT	PRESENT EMPLOYMENT	U
	PRESENT UNEMPLOYMENT (1972 regional)	7.4% (Athol Labor Area)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	140
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

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PROFILE: Belmont

B. RECEIVERS

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	4.6 sq. mi.
	CHARACTER:	Urban/Boston suburb or satellite; residential
	TOTAL ACREAGE TAKEN FOR PROJECT: N/A	
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	28,285; 6,162/sq. mi.
	AGE COMPOSITION:	55.2% 20-64 yrs.
	RACIAL COMPOSITION	
	White ; Negro; Other	99.7%; .1%; .2%
	Foreign Stock (24.0% Canad.; 20.8% Ital.; 16.1% Irish; 8.2% Russ.; 7.7% U.K.)	45.3%
	GROWTH TRENDS	
	1960-1970:	1.5% decr.; net out-migration 1,590
	1955-1965:	0.0% chg.; net out-migration 1,604
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1971	$251,543,100
	TOTAL REVENUES, 1971	$ 9,935,952
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	219
	Wholesale (31 firms) 1970 Payroll	$2,348,468
	Retail (188 firms) Per Capita Sales	$ 1,231
5. HOUSING	NEW UNITS BUILT, 1960-1970	952
	EXISTING UNITS, 1970	9,684
	VACANCY RATE, 1960	.7%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1970)	4,830; 824
	PRESENT CLASSROOM SPACE, K-12	221 classrooms
	TEACHERS CURRENTLY EMPLOYED	231
	PUPIL-TEACHER RATIO: Elementary; Secondary	21.9; 18.1
	TEACHER SALARY RANGE (1971)	$7,525 - $16,375
	COST PER PUPIL (1970-1971)	$900
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	N/A

Unobtainable data at this level of detail
N/A=not applicable

PROFILE: Belmont

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	
	Developed Park Land:	56 acres
	Undeveloped Conservation Land	67 acres
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	N/A
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS	Mass. #2,#60,#16
	AIR	Logan Int. Airport
	RAIL	Boston & Maine RR (freight)
	BUS	MBTA - 5 franchises
	GENERAL	All Boston facilities
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	MDC Member
	PRESENT GARBAGE COLLECTION SYSTEM	Yes
	PRESENT RESIDENTIAL INSURANCE RATE	$4-$5/$1000 per year
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE	Extremely low level of interest: average of 3 groups per community; 2 in favor, 1 opposed to project
	Positive Statements	
	Negative Statements	
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	U-- Est. average of 2 per community: 1 conservation group & 1 service club
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	1 (Planning Board)
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	N/A
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Belmont

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1970 (66 firms)	$ 4,242,297
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll, 1970 (449 firms)	$21,924,471
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 8,372
	PRESENT TAX REVENUE, 1971	$9,935,952
	REGIONAL INCOME 1959 Median Family Income, Middlesex County	$ 6,853
18. EMPLOYMENT	PRESENT EMPLOYMENT,	U
	PRESENT UNEMPLOYMENT (1972 regional)	6.2% (Boston SMSA)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS, 1970	449
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: Boston

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	43.18 sq. mi.
	CHARACTER:	Urban/city core
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	641,071; 14,846/sq. mi.
	AGE COMPOSITION	55.0% 20-64 yrs.
	RACIAL COMPOSITION White; Negro; Other	90.2%; 9.1%; .8%
	Foreign Stock: (23.5% Irish; 18.6% Ital.; 17.5% Canad.; 10.1% Russ.; 6.3% U.K.)	45.5%
	GROWTH TRENDS 1960-1970:	8.0% decr.; net out-migration 101,862
	1955-1965:	15.0% decr.; net out-migration 171,869
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1970	$1,617,000,000
	TOTAL REVENUES, 1970	$ 253,545,600
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	$388,437,375
	Wholesale (2343 firms) 1970 Payroll	$ 2,385
	Retail (6,230 firms) 1967 Per Capital Sales	
5. HOUSING	NEW UNITS BUILT, 1960-1970	38,345
	EXISTING UNITS, 1960	238,802
	VACANCY RATE, 1960	3.9%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1970)	97,574; 33,545
	PRESENT CLASSROOM SPACE, K-12	4,159 classrooms
	TEACHERS CURRENTLY EMPLOYED	4,331
	PUPIL-TEACHER RATIO: Elementary; Secondary	20.9; 17.4
	TEACHER SALARY RANGE	$7,600 - $15,300
	COST PER PUPIL	$741
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	N/A

Unobtainable data at this level of detail
N/A=not applicable

PROFILE: Boston

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS Main Park System Miscellaneous Parks Public Grounds & Squares Marine Park Playgrounds 1990 RECREATION PLAN	2258.26 acres 1157.23 316.06 51.03 87 646.94 U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	N/A
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS AIR RAIL BUS OTHER	Mass. Tpke. (Int. Rte. 90) Logan Int. Airport A regional terminal 20 franchises Boston Harbor
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM PRESENT GARBAGE COLLECTION SYSTEM PRESENT RESIDENTIAL INSURANCE RATE	MDC Member Yes $4-$5/$1000 per year
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	Extremely low level of interest: average of 3 groups per community; 2 in favor, 1 opposed to project
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	U-- Est. average of 2 per community: 1 conservation group & 1 service club
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	U--several, incl. Boston Redevt. Authority, var. historical groups
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST. APPLICATIONS TO M.D.C. FOR SERVICE	N/A N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Boston

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1970 (1,099 firms)	$ 213,201,039
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll, 1970 (18,194 firms)	$2,922,332,362
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 5,747
	PRESENT TAX REVENUE , 1970	$253,545,600
	REGIONAL INCOME 1959 Median Family Income, Suffolk County	$ 5,756
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960	
	Private	303,567
	Government	231,956
	Self-Employed	39,851
	Unpaid Family Workers	15,308
		577
	PRESENT UNEMPLOYMENT (1972 regional)	6.2% (Boston SMSA)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS , 1970	18,194
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: **Braintree**

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	13.70 sq. mi.
	CHARACTER:	Urban; moderately residential; industrial economy
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1965; DENSITY	33,954; 2,478/sq. mi.
	AGE COMPOSITION	50.8% 20-64 yrs.
	RACIAL COMPOSITION White; Negro; Other	99.8%; .1%; .1%
	Foreign Stock: (30.0% Canad.; 17.7% Ital.; 17.3% U.K.; 14.5% Irish; 4.8% Swed.)	36.3%
	GROWTH TRENDS 1950-1960:	34.1% inc.; net in-migration 4,333
	1955-1965:	27.2% inc.; net in-migration 5,138
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1969	$95,059,350
	TOTAL REVENUES, 1969	$ 9,125,698
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	191
	Wholesale (34 firms) 1968 Payroll	$5,278,241
	Retail (157 firms) 1967 Per Capita Sales	$ 2,984
5. HOUSING	NEW UNITS BUILT, 1960-1970	1,790
	EXISTING UNITS, 1960	8,608
	VACANCY RATE, 1960	.6%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1968-1969)	8,768; 1,248
	PRESENT CLASSROOM SPACE, K-12 (1971)	345 classrooms
	TEACHERS CURRENTLY EMPLOYED (1968-1969)	328
	PUPIL-TEACHER RATIO: Elementary; Secondary	24.6; 22.7
	TEACHER SALARY RANGE	$6,800 - $12,500
	COST PER PUPIL	$720
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	N/A

Unobtainable data at this level of detail
N/A=not applicable

PROFILE: **Braintree**

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	280 acres
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	N/A
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS RAIL BUS	Mass.#128,#3,#37,#53 Penn Central RR (freight) MBTA Member
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM PRESENT GARBAGE COLLECTION SYSTEM PRESENT RESIDENTIAL INSURANCE RATE	Town water supply (groun & surface) U $4-$5/$1000 per year
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	Extremely low level of interest: average of 3 groups per community; 2 in favor, 1 opposed to project
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	U-- Est. average of 2 per community: 1 conservation group & 1 service club
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	3 (Planning Board; Chamber of Commerce; Indus. Devt. Comm.)
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST. APPLICATION TO M.D.C. FOR SERVICE (a no-option community)	N/A Yes--feasibility study underway

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: **Braintree**

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968 (84 firms)	$ 9,780,446
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll, 1968 (549 firms)	$76,182,791
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 7,474
	PRESENT TAX REVENUE, 1969	$9,125,698
	REGIONAL INCOME 1959 Median Family Income, Norfolk County	$ 7,366
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960 Private Government Self-Employed Unpaid Family Workers	11,199 8,882 1,521 772 24
	PRESENT UNEMPLOYMENT (1972 regional)	6.2% (Boston SMSA)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	549
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: **Medfield**

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	14.43 sq. mi.
	CHARACTER:	Residential
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	9,821; 681/sq. mi.
	AGE COMPOSITION:	52.8% 20-64 yrs.
	RACIAL COMPOSITION White; Negro; Other	99.4%; .4%; .2%
	Foreign Stock (29.7% Canad.; 16.2% Irish; 13.1% U.K.; 9.9% Ital.; 4.9% Russ.):	39.8%
	GROWTH TRENDS 1950-1960:	%chg. U; net in-migration 882
	1955-1965:	41.3% inc.; net in-migration 1,386
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION,1970	$58,487,690
	TOTAL REVENUES, 1970	$ 2,514,970
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	31
	Wholesale (8 firms) 1968 Payroll	$190,645
	Retail (23 firms)1968 Payroll	$936,635
5. HOUSING	NEW UNITS BUILT, 1960-1970	1,152
	EXISTING UNITS, 1960	1,346
	VACANCY RATE, 1960	3.9%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1969)	2,579; 271
	PRESENT CLASSROOM SPACE, K-12 (1971)	146 classrooms
	TEACHERS CURRENTLY EMPLOYED (1969-1970)	135
	PUPIL-TEACHER RATIO: Elementary; Secondary	21.2; 16.7
	TEACHER SALARY RANGE	$7,100 - $12,300
	COST PER PUPIL	$764
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	N/A

U=unobtainable data at this level of detail
N/A=not applicable

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	10.2 acres
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	N/A
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS	Mass. #27, #109
	AIR	Norwood Mun. A.; Norfolk Mun. A.
	RAIL	Penn Central RR (freight)
	BUS	2 franchises
	TRUCK	Local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	Town Water Dept.
	PRESENT GARBAGE COLLECTION SYSTEM	Yes
	PRESENT RESIDENTIAL INSURANCE RATE	$4-$5/$1000 per year
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	Extremely low level of interest: average of 3 groups per community; 2 in favor, 1 opposed to project
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	U-- Est. average of 2 per community: 1 conservation group & 1 service club
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	3 (Planning Board; Historical Society; Industrial Devt. Comm.)
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	N/A
	APPLICATIONS TO M.D.C. FOR SERVICE	No

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Medfield

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968 (16 firms)	$ 686,090
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll, 1968 (92 firms)	$3,778,550
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 7,535
	PRESENT TAX REVENUE , 1970	$2,514,970
	REGIONAL INCOME 1959 Median Family Income, Norfolk County	$ 7,366
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960	1,842 (695 in 1968 at Medf. State Hosp)
	Private	1,217
	Government	435
	Self-Employed	185
	Unpaid Family Workers	5
	PRESENT UNEMPLOYMENT (1972 regional)	6.2% (Boston SMSA)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	92
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: Medford

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	8.22 sq. mi.
	CHARACTER:	Urban/Boston satellite or suburb; residential
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	
2. POPULATION	TOTAL, 1970; DENSITY	64,397; 7,844/sq. mi.
	AGE COMPOSITION:	54.1% 20-64 yrs.
	RACIAL COMPOSITION White; Negro; Other	98.2%; 1.7%; .1%
	Foreign Stock: (39.8% Ital.; 21.5% Canad.; 15.7% Irish; 7.0% U.K.; 3.5% Russ.)	46.2%
	GROWTH TRENDS 1950-1960:	1.7% dec.; net out-migration 8,410
	1955-1965:	7.6% dec.; net out-migration 11,221
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1969	$123,781,700
	TOTAL REVENUES 1969	$ 15,844,058
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	309
	Wholesale (74 firms) 1968 Payroll	$7,997,422
	Retail (235 firms) 1967 Per Capita Sales	$ 1,971
5. HOUSING	NEW UNITS BUILT, 1960-1970	1,206
	EXISTING UNITS, 1960	18,756
	VACANCY RATE, 1960	1.0%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1968-1969)	10,606; 3,892
	PRESENT CLASSROOM SPACE, K-12 (1971)	452 classrooms
	TEACHERS CURRENTLY EMPLOYED (1968-1969)	336
	PUPIL-TEACHER RATIO: Elementary; Secondary	26.5; 25.5
	TEACHER SALARY RANGE (1969-1970)	$6,400 - $12,350
	COST PER PUPIL (1968-1969)	$662
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	N/A

N/A=not applicable

PROFILE: Medford

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	17,670 acres
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	N/A
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS	U.S.#1; Int.#93
	AIR	Logan Int'l Airport
	RAIL	All Boston facilities
	BUS	All Boston facilities
	OTHER	Channel to Boston Harbor
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	MDC Member
	PRESENT GARBAGE COLLECTION SYSTEM	Yes
	PRESENT RESIDENTIAL INSURANCE RATE	$4-$5/$1000 per year
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	Extremely low level of interest: average of 3 groups per community; 2 in favor, 1 opposed to project
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	U-- Est. average of 2 per community: 1 conservation group & 1 service club
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	3 (Planning Board; Chamber of Commerce; Indust. Devt. Comm.)
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	N/A
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Medford

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968 (128 firms)	$ 9,593,786
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll , 1968 (853 firms)	$64,924,468
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 6,693
	PRESENT T[illegible] REVENUE , 1969	$15,844,058
	REGIONAL INCOME 1959 Median Family Income, Middlesex County	$ 6,853
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960	26,379
	Private	21,225
	Government	3,218
	Self-Employed	1,936
	Unpaid Family Workers	98
	PRESENT UNEMPLOYMENT (1972 regional)	6.2% (Boston SMSA)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS, 1968	853
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

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PROFILE: **Natick**

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	14.88 sq. mi.
	CHARACTER:	Urban/indep.; mixed economy--highly industrial
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	31,057; 2,087/sq. mi.
	AGE COMPOSITION:	50.7% 20-64 yrs.
	RACIAL COMPOSITION White ; Negro; Other	99.5%; .3%; .2%
	Foreign Stock: (29.4% Canad.; 15.8% Ital.; 12.2% U.K.; 12.1% Irish; 7.5% Russ.)	34.3%
	GROWTH TRENDS 1950-1960:	45.3% inc.; net in-migration 4,084
	1955-1965:	15.8% inc.; net out-migration 760
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1969	$178,451,600
	TOTAL REVENUES, 1969	$ 9,707,766
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	254
	Wholesale (53 firms) 1968 Payroll	$13,289,533
	Retail (201 firms) 1967 Per Capita Sales	$ 3,587
5. HOUSING	NEW UNITS BUILT, 1960-1970	1,130
	EXISTING UNITS, 1960	7,993
	VACANCY RATE, 1960	1.2%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1968-1969)	8,474; 895
	PRESENT CLASSROOM SPACE, K-12 (1971)	369 classrooms
	TEACHERS CURRENTLY EMPLOYED (1968-1969)	244
	PUPIL-TEACHER RATIO: Elementary; Secondary	26.5; 22.2
	TEACHER SALARY RANGE	$6,700 - $12,400
	COST PER PUPIL	$693
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	N/A

Unavailable data at this level of detail
N/A=not applicable

PROFILE: Natick

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	378.8 acres
	1990 RECREATION PLAN	Yes
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	N/A
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS	Mass.#9, Worcester Tpke; Int. 90, Mass. Tpke; Mass.#16,#27,#135
	RAIL	Penn Central RR (passenger & freight)
	BUS	5 franchises
	TRUCK	Local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	Town Water Supply (ground sources); meager drainage facilities
	PRESENT GARBAGE COLLECTION SYSTEM	Yes
	PRESENT RESIDENTIAL INSURANCE RATE	$4-$5/$1000 per year
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	Extremely low level of interest: average of 3 groups per community; 2 in favor, 1 opposed to project
12. COMMUNITY INAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	U-- Est. average of 2 per community: 1 conservation group & 1 service club
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	4 (Planning Board; Recreation Comm.; Chamber of Comm.; Indust. Council)
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	N/A
	APPLICATIONS TO M.D.C. FOR SERVICE	No

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Natick

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968 (87 firms)	$ 4,343,723
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll, 1968 (624 firms)	$68,656,765
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 7,550
	PRESENT TAX REVENUE, 1969	$9,707,766
	REGIONAL INCOME 1959 Median Family Income, Middlesex County	$ 6,853
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960	11,195
	Private	8,715
	Government	1,393
	Self-Employed	931
	Unpaid Family Workers	27
	PRESENT UNEMPLOYMENT (1972 regional)	6.2% (Boston SMSA)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	624
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: Northborough

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	18.47 sq. mi.
	CHARACTER:	Rural; moderately residential
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	9,218; 499/sq. mi.
	AGE COMPOSITION	47.8% 20-64 yrs.
	RACIAL COMPOSITION White ; Negro; Other	99.6%; --; .3%
	Foreign Stock: (38.8% Canad.; 13.8% U.K.; 11.2% Swed.; 6.2% Irish; 5.8% Polish)	23.6%
	GROWTH TRENDS 1950-1960: 1955-1965:	114.2% inc.; net in-migration 2,600 68.2% inc.; net in-migration 1,989
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION,1970	$45,241,255
	TOTAL REVENUES, 1970	$ 2,470,172
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale) Wholesale (3 firms) 1968 Payroll Retail (37 firms) 1967 Per Capita Sales	40 $36,871 $ 861
5. HOUSING	NEW UNITS BUILT, 1960-1970	789
	EXISTING UNITS, 1960	1,900
	VACANCY RATE, 1960	2.4%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1969-1970)	2,642; 238
	PRESENT CLASSROOM SPACE, K-12 (1971)	178 classrooms
	TEACHERS CURRENTLY EMPLOYED (1969-1970)	107
	PUPIL-TEACHER RATIO: Elementary; Secondary	17.5; U
	TEACHER SALARY RANGE (1970)	$7,100 - $13,780
	COST PER PUPIL (1969-1970)	$703
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	N/A

U=obtainable data at this level of detail
N/A=not applicable

borough

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	40 acres
	State-Owned Land (Sanctuary)	100 acres
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	N/A
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS	U.S.#20; Mass.#135
	RAIL	Penn Central RR (freight)
	AIR	Worcester Municipal Airport
	BUS	4 franchises
	TRUCK	Local & long-distance service
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	Town Water Dept.
	PRESENT GARBAGE COLLECTION SYSTEM	Yes
	PRESENT RESIDENTIAL INSURANCE RATE	$4-$5/$1000 per year
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	Extremely low level of interest: average of 3 groups per community; 2 in favor, 1 opposed to project
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	U-- Est. average of 2 per community: 1 conservation group & 1 service club
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	3 (Planning Board; Historical Society; Industrial Devt. Commission)
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	N/A
	APPLICATIONS TO M.D.C. FOR SERVICE	No

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Northborough

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968 (19 firms)	$ 571,631
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll , 1968 (114 firms)	$4,791,667
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 6,784
	PRESENT TAX REVENUE , 1970	$2,470,172
	REGIONAL INCOME 1959 Median Family Income, Worcester County	$ 5,977
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960	2,263
	Private	1,758
	Government	282
	Self-Employed	223
	Unpaid Family Workers	12
	PRESENT UNEMPLOYMENT (1972 regional)	7.8% (Worcester SMSA)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	114
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: **Peabody**

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	16.45 sq. mi.
	CHARACTER:	Urban/Independent; highly industrial
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	48,080; 2,923/sq. mi.
	AGE COMPOSITION:	52.1% 20-64 yrs.
	RACIAL COMPOSITION White; Negro; Other	99.8%; .1%; .1%
	Foreign Stock (19.9% Canad.; 15.1% Irish; 12.5% Ger.; 10.3% Russ.; 8.9% Polish)	44.2%
	GROWTH TRENDS 1950-1960:	42.2% inc.; net in-migration
	1955-1965:	56.6% inc.; net in-migration 10,368
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION, 1969	$83,384,540
	TOTAL REVENUES,1969	$ 9,839,376
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	294
	Wholesale (61 firms) 1968 Payroll	$2,775,145
	Retail (233 firms) 1967 Per Capita Sales	$ 2,598
5. HOUSING	NEW UNITS BUILT, 1960-1970	4,586
	EXISTING UNITS, 1960	9,907
	VACANCY RATE, 1960	2.3%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1968-1969)	9,689; 2,137
	PRESENT CLASSROOM SPACE, K-12 (1971)	450 classrooms
	TEACHERS CURRENTLY EMPLOYED (1968-1969)	334
	PUPIL-TEACHER RATIO: Elementary; Secondary	25.8; 25.6
	TEACHER SALARY RANGE (1969-1970)	$6,200 - $11,200
	COST PER PUPIL (1968-1969)	$658
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	N/A

[illegible] at this level of detail
N/A = not applicable

PROFILE: **Peabody**

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS Parks School Playgrounds Undeveloped Areas 1990 RECREATION PLAN	404 acres 102 acres 177 acres 125 acres U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	N/A
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS AIR RAIL BUS	U.S.#1, Mass.#128; Int.#95 Logan I.A.; Beverly, Danvers Boston & Maine RR (freight) 4 franchises
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM PRESENT GARBAGE COLLECTION SYSTEM PRESENT RESIDENTIAL INSURANCE RATE	MDC Member Yes $4-$5/$1000 per year
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	Extremely low level of interest: average of 3 groups per community; 2 in favor, 1 opposed to project
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	U-- Est. average of 2 per community: 1 conservation group & 1 service club
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	3 (Planning Board; Chamber of Commerce; Indust. Devt. Comm.)
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST. APPLICATIONS TO M.D.C. FOR SERVICE	N/A N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: **Peabody**

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968 (108 firms)	$ 524,817
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll, 1968 (782 firms)	$67,894,572
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 6,479
	PRESENT TAX REVENUE, 1969	$9,839,376
	REGIONAL INCOME 1959 Median Family Income, Essex County	$ 6,313
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960	
	Private	12,638
	Government	10,331
	Self-Employed	1,298
	Unpaid Family Workers	974
		35
	PRESENT UNEMPLOYMENT (1972 regional)	6.2% (Boston SMSA)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	782
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

Town: Randolph

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	10.08 sq. mi.
	CHARACTER:	Urban independent; moderately resid.; highly industrial
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	27,035; 2,682/sq. mi.
	AGE COMPOSITION:	50.1% 20-64 yrs.
	RACIAL COMPOSITION White; Negro; Other	98.9%; 1.0%; .1%
	Foreign Stock: (27.8% Canad.; 14.2% Irish; 11.8% Ital.; 11.1% Russ.; 9.7% U.K.)	33.6%
	GROWTH TRENDS 1950-1960:	89.3% inc.; net in-migration 6,093
	1955-1965:	60.5% inc.; net in-migration 4,650
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION,1970	$116,836,755
	TOTAL REVENUES, 1970	$ 7,010,205
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale)	125
	Wholesale (20 firms)' 1968 Payroll	$1,488,194
	Retail (105 firms) 1967 Per Capita Sales	$ 1,211
5. HOUSING	NEW UNITS BUILT, 1960-1970	2,914
	EXISTING UNITS, 1960	4,984
	VACANCY RATE, 1960	1.4%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1969-1970)	6,773; 983
	PRESENT CLASSROOM SPACE, K-12 (1971)	283 classrooms
	TEACHERS CURRENTLY EMPLOYED (1969-1970)	305
	PUPIL-TEACHER RATIO: Elementary; Secondary	24.5; 19.0
	TEACHER SALARY RANGE (1970)	$7,200 - $12,600
	COST PER PUPIL (1969-1970)	$730
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	N/A

Unpublished data at this level of detail
N/A=not applicable

PROFILE: **Randolph**

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	U
	1990 RECREATION PLAN	U
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	N/A
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS:	Mass.#128,#24,#28,#139,Fall R. Expy.
	AIR:	Norwood M.A.; Logan Int. Airport
	RAIL:	Penn Central RR (freight)
	BUS:	6 franchises
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	Town Water Dept.
	PRESENT GARBAGE COLLECTION SYSTEM	Yes
	PRESENT RESIDENTIAL INSURANCE RATE	$4-$5/$1000 per year
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	Extremely low level of interest: average of 3 groups per community; 2 in favor, 1 opposed to project
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	U-- Est. average pf 2 per community: 1 conservation group & 1 service club
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	3 (Planning Board; Indus. Devt. Comm.; Chamber of Commerce)
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	N/A
	APPLICATION TO M.D.C. FOR SERVICE (a no-option community)	Yes--feasibility study underway

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Randolph

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968 (63 firms)	$ 2,190,497
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll, 1968 (346 firms)	$25,471,289
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 6,883
	PRESENT TAX REVENUE, 1970	$7,010,205
	REGIONAL INCOME 1959 Median Family Income, Norfolk County	$ 7,366
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960	6,479
	Private	5,180
	Government	825
	Self-Employed	474
	Unpaid Family Workers	9
	PRESENT UNEMPLOYMENT (1972 regional)	6.2% (Boston SMSA)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	346
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

PROFILE: Revere

CATEGORY	MEASURE	
1. LAND USE	TOTAL AREA:	5.95 sq. mi.
	CHARACTER:	Urban/Residential (resort)
	TOTAL ACREAGE TAKEN FOR PROJECT:	N/A
	USE IN PROJECT AREA:	N/A
2. POPULATION	TOTAL, 1970; DENSITY	43,159; 7,254/sq. mi.
	AGE COMPOSITION, 1965	56.6% 20-64 yrs.
	RACIAL COMPOSITION White; Negro; Other	99.6%; .4%; .1%
	Foreign Stock: (45% Ital.; 14.8% Russ.; 14.3% Canad.; 7.3% Irish; 6.1% U.K.)	48.6%
	GROWTH TRENDS 1950-1960:	9.0% incr.; net out-migration 1,307
	1955-1965:	7.1% incr.; net out-migration 1,327
3. MUNICIPAL FINANCE	TOTAL ASSESSED VALUATION,1970	$ 87,165,250
	TOTAL REVENUES, 1970	$12,098,536
	ASSESSMENTS IN PROJECT AREA	N/A
4. COMMERCIAL ACTIVITY	TOTAL BUSINESS FIRMS (Retail & Wholesale) Wholesale (30 firms) 1968 Payroll	$4,181,715
	Retail (413 firms) Per Capita Sales	$ 1,854
5. HOUSING	NEW UNITS BUILT, 1960-1970	2,410
	EXISTING UNITS, 1970	15,110
	VACANCY RATE, 1960	1.6%
6. EDUCATION	PRESENT ATTENDANCE, K-12: Public; Private (1969-1970)	7,687; 1,239
	PRESENT CLASSROOM SPACE, K-12	302 classrooms
	TEACHERS CURRENTLY EMPLOYED	301
	PUPIL-TEACHER RATIO: Elementary; Secondary	26.7; 17.4
	TEACHER SALARY RANGE (1970)	$6,600 - $13,950
	COST PER PUPIL	$800
	PRESENT BUSING	N/A
	PRESENT "LIVING LABORATORY" OPPORTUNITIES	N/A

U=unobtainable data at this level of detail
N/A=not applicable

PROFILE: Revere

CATEGORY	MEASURE	
7. LEISURE OPPORTUNITIES	TOTAL ACREAGE OF PARKS AND PLAYGROUNDS	47 acres
	1990 RECREATION PLAN	N/A
8. CULTURAL OPPORTUNITIES	NUMBER OF CHURCHES, HISTORICAL SITES TAKEN IN LAND ACQUISITION	N/A
9. TRANSPORTATION	PRESENT MAJOR ARTERIES, HIGHWAYS	Interstate #95
	RAIL	Boston & Maine RR (freight)
	AIR	Logan Int. Airport
	BUS	6 franchises, incl. MBTA
	GENERAL	All Boston facilities
10. MUNICIPAL SERVICES	PRESENT WATER AND SEWERAGE SYSTEM	MDC Member
	PRESENT GARBAGE COLLECTION SYSTEM	Yes
	PRESENT RESIDENTIAL INSURANCE RATE	$4-$5/$1000 per year
11. SECURITY	PRESENT ATTITUDES TOWARD SYSTEM FAILURE Positive Statements Negative Statements	Extremely low level of interest; average of 3 groups per community, 2 in favor, 1 opposed
12. COMMUNITY IMAGE	PRESENT COMMUNITY IMAGE*	
13. COMMUNITY COHESIVENESS	NUMBER OF ACTIVE COMMUNITY GROUPS WITH ENVIRONMENTAL INTERESTS	U-- Est. average of 2 per community: 1 conservation group & 1 service club
14. CITIZEN INVOLVEMENT	NUMBER OF COMMUNITY GROUPS INVOLVED IN PROJECT PLANNING	3 (Planning Board; Chamber of Commerce; Indust. Devt. Comm.)
15. INSTITUTIONAL INVOLVEMENT	NUMBER OF JURISDICTIONS AFFECTED BY PROPOSED PROJECT CONST.	N/A
	APPLICATIONS TO M.D.C. FOR SERVICE	N/A

* Our information on community self-image was derived from field interviews rather than from content analysis.

PROFILE: Revere

CATEGORY	MEASURE	
16. ECONOMIC STABILITY	PRESENT INCOME FROM CONSTRUCTION ACTIVITIES: Annual Payroll, 1968 (73 firms)	$ 2,624,029
	PRESENT VALUE OF PRIVATE SECTOR COMPANIES: Total Annual Payroll; 1968 (624 firms)	$25,526,721
17. REAL INCOME	MEDIAN FAMILY INCOME, 1960	$ 5,971
	PRESENT TAX REVENUE, 1970	$12,098,536
	PRESENT REGIONAL INCOME 1959 Median Family Income, Suffolk County	$ 5,756
18. EMPLOYMENT	PRESENT EMPLOYMENT, 1960 Private Government Self-Employed Unpaid Family Workers	12,154 1,901 1,399 24
	PRESENT UNEMPLOYMENT (1972 regional)	6.2% (Boston SMSA)
19. INDUSTRIAL ACTIVITY	NUMBER OF INDUSTRIAL FIRMS	624
	PRESENT VALUE ADDED, MANUFACTURES	U
20. AGRICULTURAL ACTIVITY	NUMBER OF FARM ACRES	U
	PRODUCTION PER ACRE	U

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APPENDIX G

PUBLIC HEALTH ASPECTS OF DIVERSION OF CONNECTICUT RIVER WATER TO QUABBIN RESERVOIR

A sanitary engineer from the Division of Air and Water Programs, Environmental Protection Agency, working in cooperation with the New England Division, U. S. Army Corps of Engineers, prepared this appendix. The work included gathering and analyzing water quality data of both the Connecticut River and Quabbin Reservoir to determine from a public health standpoint the acceptability of diverting Connecticut River water to Quabbin via the Northfield Mountain Pumped Storage Project. Results of this study, together with New England Research's water quality work, were used to formulate an acceptable project and aid in the design of the necessary water supply facilities.

APPENDIX G

PUBLIC HEALTH ASPECTS OF DIVERSION OF CONNECTICUT RIVER WATER TO QUABBIN RESERVOIR

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APPENDIX G

PUBLIC HEALTH ASPECTS OF DIVERSION OF CONNECTICUT RIVER WATER TO QUABBIN RESERVOIR

1. Foreword

This appendix was prepared by a sanitary engineer from the Division of Air and Water Programs, Environmental Protection Agency, in cooperation with the Army Corps of Engineers.

2. Introduction

A. Objective

The shortage of water in the Metropolitan District Commission district has required the search for more water to supplement the inadequate supply of the present system. The Massachusetts legislature has approved the diversion of a small percentage of Connecticut River flow to Quabbin Reservoir. The diversion would be contingent upon a flow at the U.S.G.S. gaging station at Montague City over 17,000 cfs. It is contemplated that the Metropolitan District Commission will normally divert 580 cfs (375 mgd) via an underground aqueduct to Quabbin Reservoir from the Northfield Mountain Pumped Storage Reservoir at the top of Northfield Mountain.

Water quality in the Connecticut River is subject to two main environmental conditions. One of these is the natural uncontrolled situations such as rainfall, erosion upstream, snow pack, soil conditions and degree of runoff and natural background. The second group of environmental conditions are those man-made, for example, discharge of municipal and industrial wastes, fluctuation of the water energy pools at Turners Falls, Vernon and Bellows Falls, farming intensity adjacent to the river and construction within the influence area of the Northfield diversion waters.

The water quality at the Northfield diversion site is also influenced by: the volume of flow past the intake, the pumping and generation at the Pumped Storage Facilities, the mixing and dilution of upstream pollution sources with the Connecticut River water flow patterns and the flow pattern through the Upper Reservoir.

The discharge of this Connecticut River water into Quabbin Reservoir and an evaluation of its effects on the quality at the MDC intake (Shaft 12) is the objective of this appendix. Included in this evaluation, is an

assessment of the potential; for mixing of the water within the reservoir; short circuiting of Connecticut River water to Shaft 12; oxygen reduction both initial and long term; and the effects of the introduction of a water with high nutrients that may create increases in phyto plankton and zoo plankton production with corresponding increases in tastes, odor, turbidity, and increased oxygen demand.

B. Limnology and Reservoirs

River water for the most part is free flowing with no thermal barriers. Quabbin Reservoir is not so free flowing and has thermal barriers that begin in April and continue to late October or early November. This thermal condition in a reservoir is called stratification and consists of three thermal zones. The upper 30 feet is called the epilimnion, a middle zone from 30 feet - 40 feet is called the metalimnion or thermocline, and a lower zone, 40 feet to reservoir bottom, is called the hypolimnion. This bottom zone has little, if any, oxygen input from May until late October. During this six month period, the organic demand in the water and the organic demand at the bottom or benthic area depletes the oxygen that was present at the time the thermal barrier was started.

The depletion, whether partial or complete (septic), depends a great deal on quantities of reducing agents in the water. These reducing agents may be micro- or macro-organisms or may be chemical in nature.

In rivers subject to industrial waste discharges, such as the Connecticut, the C.O.D. and $B.O.D._{20}$ is higher than under natural conditions. Thus the demand on the supply of oxygen -- both bacteriological and chemical demand -- in a reservoir can be high. Under some cases, this demand from incoming waters and natural reservoir demand can be so high that the hypolimnion zones may become void of oxygen during the thermal stagnation period.

The consequences of a septic condition are many fold. One example would be a loss of cold water fish that normally occupy this deep cold zone, a second and very important factor in water quality is the reduction of iron and manganese to the ferrous and manganous state, and the reduction of sulfate to hydrogen sulfide gas. The gas in the water will result in obnoxious odors. The iron and manganese will cause turbidity problems which will affect chlorination as well as cause staining problems on clothes and household fixtures in the distribution system as well as impart a taste in the water.

Besides the bacteriological and chemical demand problems, there is a third problem of nutrients common in river waters receiving domestic and industrial wastes. These nutrients, once in a standing water, are the sources of energy for phytoplankton (plants), aquatic weeds and zooplankton (animal). Metabolism of these plants and animals creates odor and biological and chemical demands on a water.

All ponds, lakes and reservoirs, from the time of their existence, begin the natural process of aging, as man begins aging at birth so does each entity. The process can be slow or rapid depending on the inputs and energy available. In the case of a reservoir, the more input of nutrients and other organics, the more biological growth and demand on the oxygen supply. The end result is an aged pond, lake or reservoir with a low quality water.

To supplement the Quabbin Reservoir supply, it has become necessary to use river water. It has been proposed to use a portion during high flows (called flood skimming) of the Connecticut River. Therefore, the potential effects of such diversion on Quabbin Reservoir must be assessed.

3. Diversion of Connecticut River Water to Quabbin Reservoir via the Northfield Mountain Project

A. Northfield Mountain

As described in the main report, diversion of Connecticut River water to Quabbin Reservoir via Northfield Mountain is presently being planned by officials of the MDC and electric company officials of Northeast Utilities.

Four companies make up Northeast Utilities Power Company -- The Connecticut Light and Power Company, The Hartford Electric Light Company, Western Massachusetts Electric Company, and The Holyoke Electric Light Company. These companies have developed the facilities for pumping and storage of water on Northfield Mountain, (Upper Reservoir), Erving, Massachusetts, and the generation of electric power from this water storage with discharge to the Connecticut River (Lower Reservoir).

Northeast Utilities Contractor is installing four pump and generating units (Reversible Turbines) each with an average pumping rate of 3,000 cfs or a total of 12,000 cfs. The release of water for power generation and its discharge to the existing Turners Falls pool on the Connecticut

River will be at the rate of about 4,500 cfs/unit or 18,000 cfs. Water will be stored in this pool and pumped again to the Upper Reservoir. The Turners Falls Dam has been raised about 6.0 feet by installation of bascule gates and hinged flash boards. The pool area is about 2,160 acres at elevation 185.00. The pond will fluctuate between a minimum elevation of 176.00 and a normal maximum of about 183.00 ±. The Turners Falls Pond is capable of holding the entire volume needed in the Upper Reservoir for power generation. The raising of the water elevation in the Lower Reservoir will affect the maximum generation at the upstream Vernon Hydroelectric Plant, and will also affect the gage reading at Vernon, Vermont. The effect will be less discharge head for turbine operation at Vernon.

The maximum operation elevation for power generation in the Upper Reservoir will be at Elevation 1,000.5 feet. At this elevation, the storage reservoir volume is 16,136 acre-feet and a surface area of 270 acres. At the minimum operating elevation of 934 feet, the storage volume (permanent pool area) will be 3,335 acre-feet, with a surface area of 115 acres. The useable generating volume is 12,750 acre-feet with an estimated energy output of 8,500 Mwhr.

The volume to be theoretically reserved for the Metropolitan District Commission water supply is from Elevation 1000.5 to Elevation 1004.5. This additional 4 feet would store 48,100,000 cubic feet or the 360 million gallons proposed for transfer to Quabbin Reservoir per day of discharge.

Using an average of 3,000 cfs per pumping unit, the 375 million gallons can be pumped to the Upper Reservoir in some 1.4 ± hours, with all four pumps operating.

The minimum time lag (1972) estimated between pumping and generating is about two hours. The proposed generating rate will be at about 18,000 cfs.

The minimum Northfield Mountain elevation drawdown will be to Elevation 934.00. The normal drawdown will be Elevation 962.00. The invert of the discharge pipe from the water supply intake tower presently under construction for the MDC is at elevation 923.00 and the reservoir bottom elevation is about elevation 900.00.

Northfield Mountain Pumped Storage Project will maintain a continuous pumping operation based initially on the previous mentioned pumping schedules. As power demand increases so will the pumping rates and time increase, and the generating frequency will also increase with time depending on power demand.

The MDC proposed diversion water will be taken from the Northfield Mountain Pumped Storage Reservoir. The quality of water at the intake will probably be a reflection of the Connecticut River Water Quality Study Results.

There has been some discussion that the pumping to Northfield Mountain would not occur when and if the quality in the river was not up to minimum standards; however, Northfield Mountain Pumped Storage Project's prime operation is generating electricity and not pumping water for the Metropolitan District Commission; therefore, the quality of water to be discharged to Quabbin Reservoir would be analyzed at the Reservoir by the electric utility. The decision made to divert or not to divert such water would have to be subject to analysis by others. The one exception to this procedure would be the monitor located on the Connecticut River required to monitor the radioactive wastes from the Vermont Yankee Nuclear Power Plant, some 12 miles upstream at Vernon, Vermont. Emergency conditions that might be created from the Vernon Plant would require close-down of the pumping operation during the periods of diversion at Northfield to prevent radioactive wastes from entering the Northfield Mountain Reservoir.

B. Vernon Hydroelectric

1) Vernon Pool

The Vernon Pool, located behind the Vernon Dam, some 12 miles upstream from the Northfield intake, has a normal elevation of 220.13 with a usable volume of 11,950 acre-feet. The maximum drawdown is five feet.

The Plant, when in full operation, discharges 12,900 cubic feet/second through its turbines. With the increase in the elevation, Turners Falls Pool, which extends to the Vernon Pool Dam, the normal discharge will be reduced, because of loss of total head.

2) Vernon Hydroelectric Operation

Operation (Relative)

Jan - April 15	14 hours/day
April 15 - June 15	24 hours/day
June 15 - Sept 15	8 hours/day
Sept 15 - Jan	14 hours/day

The operation is based on the flow of the river. Flows at Vernon of less than 12,000 cfs will result in less hours of operation due to the limit of volume in the Pool. The maximum drawdown, when reached, requires the refilling of the Pool before start-up for power generation.

Therefore, in the summer months, operation is limited to about eight hours/day, whereas during the spring, the operation is extended to twenty-four hours/day. These variations in the release of water from Vernon affect the percentage of Ashuelot River water to total flow in the Northfield diversion area.

C. Vermont Yankee Nuclear Power Plant

1) Location

The Vermont Yankee Nuclear Power Station is located some 14 miles north of the proposed Northeast Pumped Storage Intake Facilities on the Connecticut River.

The Vermont Plant is a boiling water reactor, with a capacity of 1593 MWt., 540 MW. It is located on a parcel of land at elevation approximately 252 MSL. The river is at elevation 220. Maximum flood elevation in 1936 was 231.4. The land area adjacent to the site is mostly used for dairy feed products and pasture. Several homes and two schools are located less than one half mile from the Plant.

The following Table shows the population densities in 1970 for distances from the Plant:

TABLE G-1

POPULATION DENSITY

* Vermont Yankee Environmental Report

Distance from Reactor Building--Miles	Population	Land Area Square Miles	Average Density Persons/Square Mile
	1970		
0-1	460	3.14	147
1-2	1,630	9.42	173
2-3	805	15.71	51
3-4	760	21.80	35
4-5	3,040	28.47	107
0-5	6,695	78.54	85
5-10	16,335	235.6	70
10-20	64,800	942.5	69
20-30	123,800	1570.8	79
30-40	265,800	2199.1	121
40-50	671,800	2827.4	238
0-50	1,149,200	7854.0	146

2) River Flows

The flow of the river is largely determined by the operation of the hydroelectric plants, reservoirs and lakes upstream of Vernon.

Major floods have occurred in November 1927 (155,000 cfs) at elevation 229.0; March 1936 (176,000 cfs) elevation 231.4; September 1938 (132,500 cfs) elevation 226.6. Since these floods, the Army Corps of Engineers has constructed extensive flood control works with 247,000 acre-feet of flood storage upstream of Vermont. Other authorized projects will increase storage above 625,000 acre-feet.

3) Water Use

a) The condenser cooling system provides the heat sink needed for steam condensation.

b) The intake structure at the river houses three -- 122,000 gpm circulating water pumps. Water from the river flows through the trash racks and gates into a mixing chamber. The velocity through racks is 1.0 fps. The water then flows through traveling screens and then to the circulating pumps. The flow of the intake structures is at elevation 190. The river's normal height is 220.

The mixing chamber is provided with vanes to mix the condenser water and the river water when various mode operations are used. There are three operating cooling modes:

(1) Total Open Cycle - Operations under these conditions, no flow would be diverted to the cooling towers. The entire flow would be discharged into the Connecticut River.

(2) Hybrid Cycle - Under this arrangement, a portion of the condenser discharge flow would be diverted to the cooling towers and then mixed with that portion not diverted, and the entire flows discharged to the river at the discharge structure.

(3) Closed Cycle - The operation under this condition would divert the complete condenser cooling waters to the cooling towers. The discharge from the cooling towers would be returned for recirculation to the condensers.

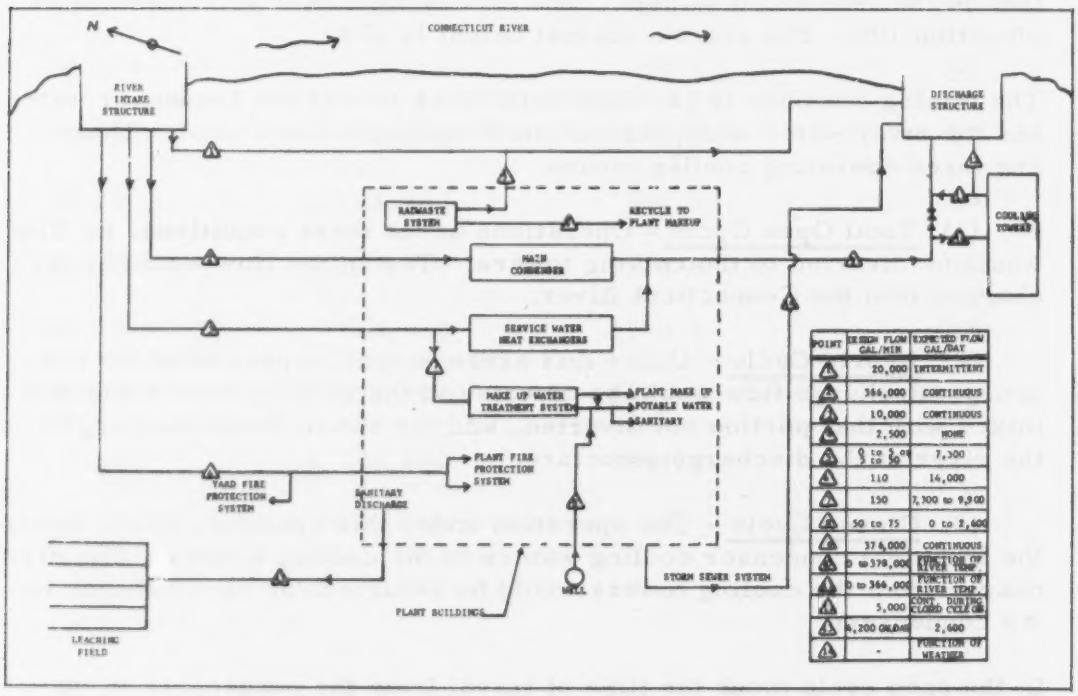
In the open cycle mode the time of travel from the condensers to the river is 2.3 minutes.

The discharge point is located some 900 feet downstream of the intake. The direction of river flow and the prevailing north to northwest wind is not expected to cause the heated water to flow into the intake structure.

4) Other Water Uses

The cooling tower operation will result in evaporation and windage losses of about 5,000 gpm. This loss to be made up from river water. Other water uses include high priority water totaling 9,900 gallons per day. Of this amount, 7,300 gallons will be returned to the river as low purity water. The remainder of 2,600 gallons will be discharged to the sub-surface sanitary waste-disposal system. An additional 5,000 gallons per minute will be required during the closed cycle operational mode.

The following plate shows the general water usage for the entire plant operations:


N
CONNECTICUT RIVER
RIVER INTAKE STRUCTURE
DISCHARGE STRUCTURE
RADWASTE SYSTEM
RECYCLE TO PLANT MAKEUP
COOLING TOWER
MAIN CONDENSER
SERVICE WATER HEAT EXCHANGERS
MAKE UP WATER TREATMENT SYSTEM
PLANT MAKE UP
POTABLE WATER
SANITARY
PLANT FIRE PROTECTION SYSTEM
YARD FIRE PROTECTION SYSTEM
SANITARY DISCHARGE
STORM SEWER SYSTEM
WELL
PLANT BUILDINGS
LEACHING FIELD
POINT | DESIGN FLOW GAL/MIN | EXPECTED FLOW GAL/DAY
1 | 20,000 | INTERMITTENT
2 | 366,000 | CONTINUOUS
3 | 10,000 | CONTINUOUS
4 | 2,500 | NONE
5 | 0 to 2,00 / 2 to 50 | 7,300
6 | 110 | 14,000
7 | 150 | 7,300 to 9,900
8 | 50 to 75 | 0 to 2,600
9 | 376,000 | CONTINUOUS
10 | 0 to 370,000 | FUNCTION OF RIVER TEMP.
11 | 0 to 366,000 | FUNCTION OF RIVER TEMP.
12 | 5,000 | CONT. DURING CLOSED CYCLE OP.
13 | 4,200 GAL/MIN | 2,600
14 | - | FUNCTION OF WEATHER

5) Radiation Exposure (Liquid Effluents)

There are four types of liquid wastes to be considered under this section:

(1) Wastes of low conductivity are of high chemical purity and are suitable for reuse in the coolant system.

(2) Low purity wastes possess a high conductivity and must be handled separately.

(3) Chemical wastes from decontamination operations and chemical reagents.

(4) Detergent wastes from the use of decontamination solutions containing detergents.

It is estimated that about 21,300 gallons per day will be produced of these four types. About 14,000 gallons are high purity wastes which are reused. Another 6,800 gallons per day is of low purity wastes, about 500 gallons per day of chemical and 10 gallons per day of detergents.

This liquid radwaste system is designed in such a way that the sum of individual radionuclide discharge structure concentration will be maintained in such a way as not to exceed 1 percent of the 10 CFR 20 limits on an annual average basis.

The Radiation Environmental Pathways are considered as two:

(1) Fish taken from the Connecticut River.

(2) Consumption of Connecticut River water for drinking purposes.

Fish Consumption

The results of the radiation studies on fish consumption, it was determined that a daily consumption of 160 grams of fish flesh for an entire year would be needed for an individual radiation exposure of less than 0.5 mRem. This level of exposure is less than 1 percent of that due to natural background.

Radiation Exposure from Quabbin Reservoir

The Yankee Nuclear studies were based on a river flow rate of 17,000 cfs. This value was used because no diversion will take place below this value.

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It was determined that the maximum dose would be less than 10 Man-rems per year for a population of 2,000,000 people. This dosage is greater than 4 orders of magnitude below the normal background dose received by those same people.

6) Effects of Released Heat

The cooling system at Vermont Yankee is designed to operate with minimal effects on the river. The Vermont Water Resources Board has established requirements for allowable temperature increases based on the ambient river water temperature. This table is listed in the report. The ambient temperature is measured 3-1/2 miles upstream of the plant. The temperature increase is measured 0.5 miles downstream of the Vernon Dam. The discharges of heated water are restricted so that the rate of change with respect to time at the temperature of the river is not to exceed upward or downward one-half (1/2) of one degree Fahrenheit from May 1 to October 31, and one degree Fahrenheit per hour from 1 November to 30 April.

Further, the Vermont Board order requires a minimum flow of 1,200 cubic feet/second through the Vernon Dam at all times.

The results of a dye study have shown that for a minimum river flow of 1,200 cfs the region of initial mixing between the heated discharge and the river flow is about 200 feet wide and 800 feet long (3.6 acres). The area is stratified, with the heated water in the first five feet of depth. Beyond this area, the heated water is intermingled with the river water.

The heated water from the condensers is approximately 20° above the initial intake river water. Although the 200' x 800' mixing area has been determined by dye tests, the actual isothermal lines will have to be determined under actual operational conditions. The use of thermal photography should be employed to follow the heat plume downstream.

The resultant river water temperature at Northfield will be unknown. There are no temperature records available on the Ashuelot River to feed into an equation. However, the rate of temperature change with respect to time will be a function of the heat decay, river flow, and the operating mode of the cooling system -- open, hybrid or closed cycle.

During the proposed diversion from the Connecticut River to Quabbin Reservoir, it is assumed that cooling system (closed or hybrid) will not be used. The mode of operation would be on open cycle.

For river water temperatures below 55° F, the assumed BTU release to the river would be about 1.3×10^{12} per month, for a 4° F river water temperature rise. For a 2° F river water temperature rise, the BTU release is assumed to be about 0.72×10^{12} per month.

During the summer months, the heat release would be limited to blow down operation. The expected temperature of 90° F would be discharged to the river. The total BTU discharge is assumed to be 3×10^{10}/month. After mixing with the minimum river flow of 1,200 cfs, the rise in river temperature is expected to be 0.146° F.

4. Connecticut River Watershed Upstream from Northfield

A. Watershed Description

The watershed area comprises some 7,160 square miles of which 114 square miles are located in the Province of Quebec, Canada. There are 3,059 square miles located in New Hampshire and 3,937 square miles within Vermont. The remainder of 50 square miles is in Massachusetts. The watershed area comprises relatively level valley and steep slopes of mountain ranges, Mt. Washington, the highest, with an elevation of 6,100 feet.

The climate of the region is, of course, milder in the south than the north. Massachusetts daily temperature in January ranges from 24° F in the north to 32° F around Northfield. The mean minimum ranges from zero in the far north to 14° F above the diversion area at Northfield.

In July, the mean maximum in the north is 74 and 82 in the south. The mean daily minimum in July is 52° F in the north and 56° F in the south.

The time between the last 32° Temperature Freeze and first 32° F Temperature in the fall is 90 days in the northern area and 120 days in the Northfield area.

The average annual melting days with 1 or more inches of snowcover is 140 in the north and 90 days at Northfield, Massachusetts.

The soils in the basin are generally acid, and are infertile. Farming is practiced along the Connecticut River Valley, chiefly dairy farming with large acreage of field corn planted along the east shore north to the Ashuelot River.

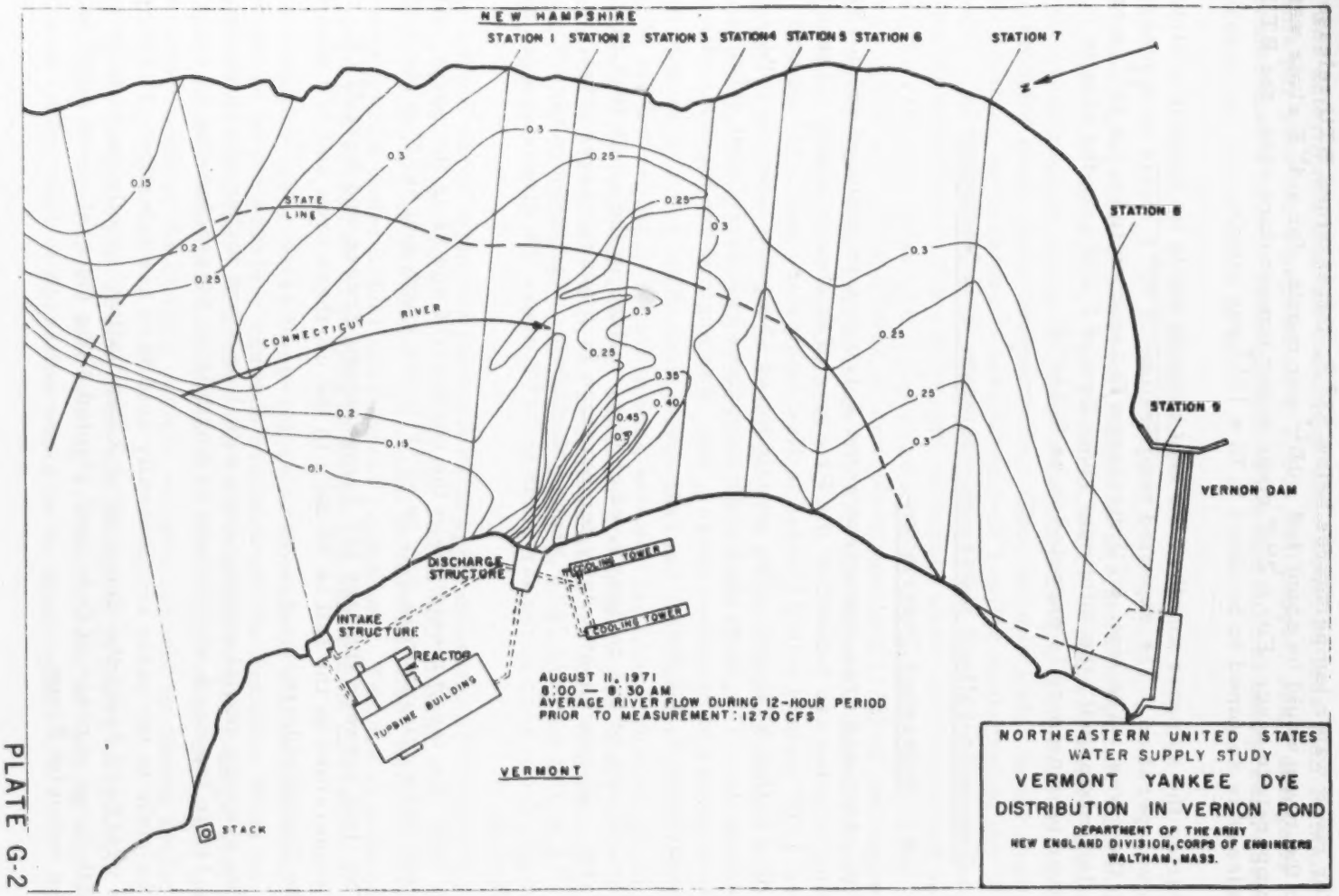
NEW HAMPSHIRE
STATION 1
STATION 2
STATION 3
STATION 4
STATION 5
STATION 6
STATION 7
STATION 8
STATION 9
VERNON DAM
STATE LINE
CONNECTICUT RIVER
0.15
0.2
0.25
0.3
0.35
0.40
0.45
0.5
0.1
DISCHARGE STRUCTURE
COOLING TOWER
COOLING TOWER
INTAKE STRUCTURE
REACTOR
TURBINE BUILDING
STACK
VERMONT
AUGUST 11, 1971
8:00 — 8:30 AM
AVERAGE RIVER FLOW DURING 12-HOUR PERIOD
PRIOR TO MEASUREMENT: 1270 CFS
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
VERMONT YANKEE DYE
DISTRIBUTION IN VERNON POND
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE G-2

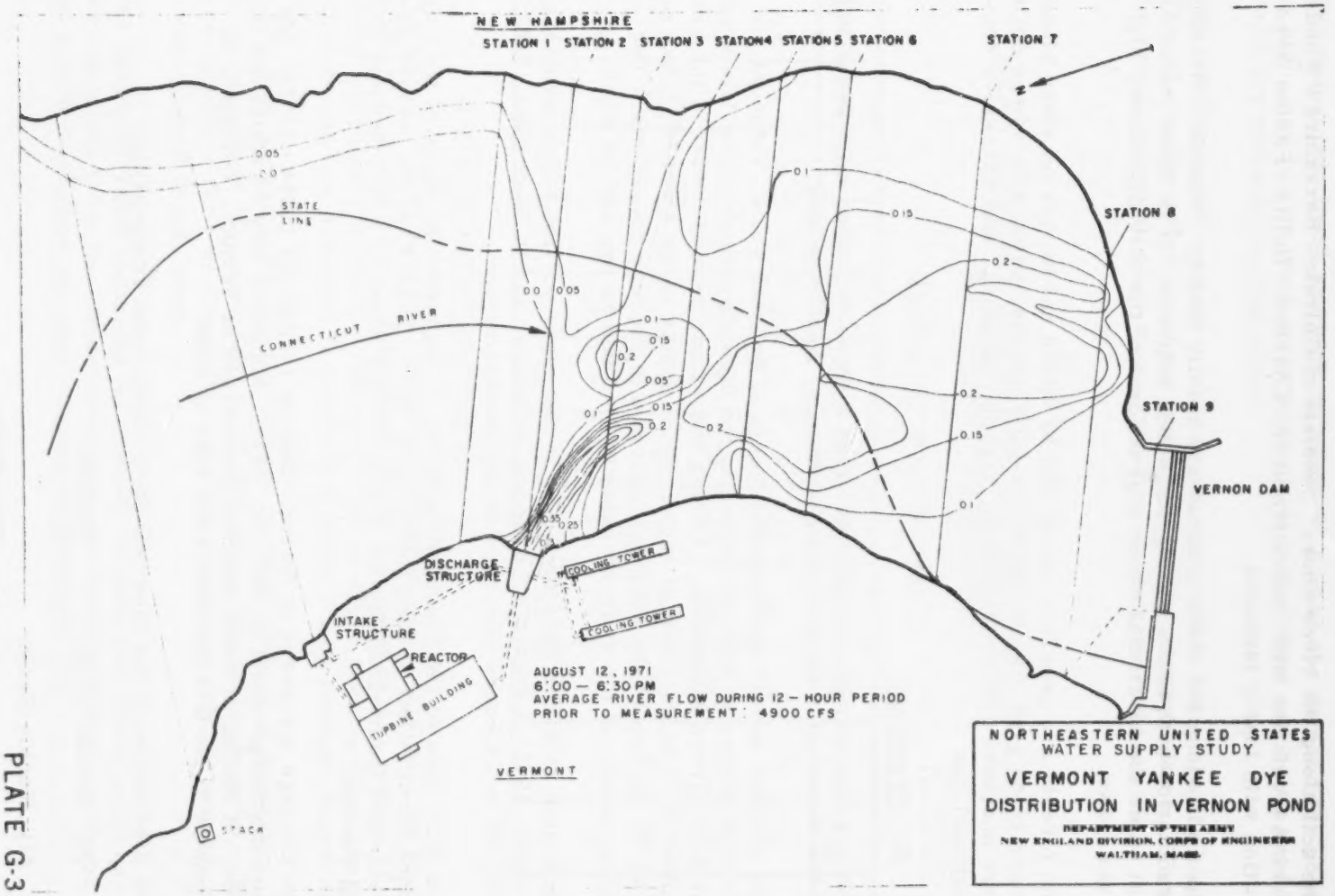
NEW HAMPSHIRE
STATION 1
STATION 2
STATION 3
STATION 4
STATION 5
STATION 6
STATION 7
STATION 8
STATION 9
VERNON DAM
STATE LINE
CONNECTICUT RIVER
0.0
0.05
0.1
0.15
0.2
0.25
0.35
DISCHARGE STRUCTURE
INTAKE STRUCTURE
REACTOR
TURBINE BUILDING
COOLING TOWER
COOLING TOWER
STACK
VERMONT
AUGUST 12, 1971
6:00 — 6:30 PM
AVERAGE RIVER FLOW DURING 12 — HOUR PERIOD
PRIOR TO MEASUREMENT: 4900 CFS
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
VERMONT YANKEE DYE
DISTRIBUTION IN VERNON POND
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE G-3

The soil along the river course consists of Colrain - Berkshire - Woodstock Association with loamy textures, Charlton - Hollis - Paxton Association with loamy textures.

The soils along the river channel are chiefly Hadley - Winooki - Windsor Association with heavy silting and sandy textures. It is these materials that enter the river that cause a great deal of the turbidity during high river flows.

The forests are generally hardwood to mixed hardwoods on steep slopes. Heavy rains give rise to rapid run-off erosions, especially where soils were uncovered by construction, logging, farming, and excessive recreational use.

B. Hydrology

The average annual run-off may be as high as 40 inches with about 50% of the annual run-off occurring in March, April and May.

The average annual precipitation north of Bellows Falls, Vermont, is about 36 inches to over 60 inches in the high elevations of the White and southern Green Mountains. During the winter months, most of the precipitation is in the form of snow. Snow depths range from 20 inches to over 40 inches in the northern part and in the high elevations. The water content of the snow amounts to 2 - 4 inches per foot of depth.

Excessive rainfalls have occurred in the upper portion of the watershed. In June, 1945, 4 inches occurred in 24 hours, and in November, 1927, 6 inches in 24 hours occurred in the central region.

The main flow of the Connecticut River is regulated by dams at the first Connecticut Lake, second Connecticut Lake, Lake Francis, Moore Reservoir and Comerford Station Pond, Wilder Reservoir and Bellows Falls and Vernon.

The average discharge at Vernon Dam is 10,060 cfs (1944 - 1967). Maximum discharge was 176,000 cfs, 1936. Minimum was 99 cfs in the fall of 1944. A listing of mean monthly discharges at Vernon, Vermont, is shown in Table G-1 for the years 1965 to 1969.

The discharges of the river all form three main components:

(1) Annual Cycle - Natural

(2) Weekly Cycle

(3) Daily Cycle - Man-Made

The man-made flows are high on week-days when the demand for power is high, and low on week-ends when storage facilities are being used to refill the pools behind the dams.

The maximum and minimum discharges vary widely from hour to hour. This shows the influence of the power generation at these dams. Thus, the flows, especially low flows, are tied to the power operations.

TABLE G-2

MEAN MONTHLY DISCHARGES OF THE CONNECTICUT AT VERNON, VERMONT

Approx. C.F.S. X 1000

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
1965	3	5	7	4	4	7	17	8	5	2	3	5
1966	8	7	6	6	5	17	23	18	8	3	5	5
1967	5	8	5	4	3	7	36	23	10	4	3	3
1968	6	6	9	4	5	23	25	14	13	7	2	3
1969	3	7	10	5	4	8	55	31	8	7	8	6

C. Available Diversion Periods

The times of diversion of Connecticut River water to Quabbin, as stated earlier, are limited by the Massachusetts Legislature Act setting 17,000 cfs at Montague City as the minimum flow at which Metropolitan District Commission can withdraw from the Northfield Pump Storage Reservoir.

It has been determined that the average number of days of diversion when the flow at Montague City is 17,000 cfs or above is about 70. The most probable time of diversion is during spring run-off, but not necessarily limited to this time.

The following Table indicates the number of days that water could have been diverted from the Connecticut River to Quabbin Reservoir based on the 17,000 or higher cfs gage reading at Montague City.

TABLE G-3

AVAILABLE DIVERSION PERIODS 1961-1971

Date of Beginning Diversion	Date of Ending Diversion (Inclusive)	Available Days for Diversion	Total Days
1961-62			
March 29	May 27	48	48
1962-63			
April 7	May 24	74	74
1963-64			
Nov. 9	Jan. 30	12	
March 6	May 17	53	65
1964-65			
April 12	May 1	20	20
1965-66			
March 3	May 25	68	68
1966-67			
March 31	June 2	64	64
1967-68			
Dec. 13	Dec. 17	5	
March 18	July 4	69	74
1968-69			
Nov. 29	Dec. 20	13	
March 25	May 28	65	
July 29	Aug. 8	8	86
1969-70			
Nov. 6	Dec. 31	28	
Feb. 4	Feb. 28	25	
March 26	May 25	58	111
1970-71			
April 3	May 28	55	55
		TOTAL DAYS	665

Ave. Discharge/Year 24.6×10^9 10 Year Ave./Year 66.5 Days

5. Connecticut River Water Quality

A. Physical Parameters

The physical qualities of the water are influenced in this watershed by the upstream topography and flows, and the intensity of human activity on the watershed.

1) Color

Colors may be influenced by temporary upstream storage in swamps and bogs, resulting in the vegetative manner being absorbed by the water. Color may also be influenced by metallic ions such as iron and manganese.

Color may also be produced by industrial plants discharging to the river. Natural or vegetable color can be expected to reduce with storage time (natural subsidence). Industrial color does not reduce with time. Dilution or treatment at the source are avenues for removal.

The color of the Connecticut River varies from 25 - 35 units during periods of proposed diversion. These are within acceptable limits for diversion of surface water with storage. Whether some of this or all is industrial color is not known.

2) Temperature

Detailed temperature records of the Connecticut River at a site 11 miles north of the proposed water supply intake have been maintained by Webster - Martin, Inc., Burlington, Vermont.

The temperature records were recorded hourly -- 24 hours a day for twelve full months from January 1, 1968 through May 31, 1971. Table G-4 lists average and monthly ranges in temperature for the years 1968 to 1971.

The greatest fluctuation in temperature occurs in April and May on a year by year basis. For example, in April 1968, the average temperature was 48.6°F; in April 1971, the average was 37.3°F. May 1968 variation on a year by year basis shows an average of 57.3°F and 1971 of 51.2°F. January, February and March show relatively even temperature difference of less than one degree over four years. June, July, August, October, November and December are also of a small differential range, while September shows about a maximum 5°F range over a three-year period (1968 - 1970) -- 73.8 in 1968 to 67.3°F in 1970.

TABLE G-4

AVERAGE AND MONTHLY RANGE OF TEMPERATURES
CONNECTICUT RIVER AT STATION 3

Approximately 11.0 Miles North of Proposed Diversion Point

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
					1968 Average and Monthly Variation							
Ave	32.2	32.7	33.0	48.6	57.3	65.1	78.4	76.3	73.8	60.7	42.0	34.3
Begin	32.1	32.6	32.7	40.7	51.2	61.5	65.4	76.0	72.9	67.6	52.5	37.0
End	32.1	32.7	39.8	49.9	60.4	71.0	76.0	73.6	67.3	54.0	37.8	32.8
					1969 Average and Monthly Variation							
Ave	32.5	32.5	32.5	40.7	53.4	68.8	75.2	73.9	70.2	57.7	44.9	33.5
Begin	33.0	32.4	32.4	32.9	46.9	63.9	73.4	72.9	76.3	63.7	48.0	36.7
End	32.4	32.5	32.8	47.9	62.6	72.4	73.7	75.3	64.0	48.5	37.2	34.0
					1970 Average and Monthly Variation							
Ave	32.8	32.2	32.3	38.8	54.8	67.8	75.5	76.7	67.3	57.6	45.7	33.5
Begin	34.0	32.4	32.3	32.6	48.3	60.2	68.9	79.4	70.8	64.7	49.1	38.9
End	32.5	32.2	32.4	46.7	59.5	68.7	79.5	72.2	65.8	49.4	39.0	32.0
					1971 Average and Monthly Variation							
Ave	32.3	32.3	32.4	37.3	51.2	68.7	73.3	74.0	69.4	58.3	46.1	33.2
Begin	32.1	32.4	32.3	32.5	40.8	57.7	76.8	77.9	69.0	64.2	56.5	34.4
End	32.6	32.4	32.6	40.1	56.4	76.5	74.1	67.3	63.8	56.5	35.6	32.2

Year	Temp. Change Over 30 Days
1968	Ave. March - April + 15.6°F Ave. April - May + 8.7°F Ave. May - June + 7.8°F
1969	Ave. March - April + 8.2°F Ave. April - May + 12.7°F Ave. May - June + 15.4°F
1970	Ave. March - April + 6.5°F Ave. April - May + 16.0°F Ave. May - June + 13.0°F
1971	Ave. March - April + 4.9°F Ave. April - May + 3.9°F Ave. May - June + 17.5°F

3) Odor

Odor tests have not been done on Connecticut River water in enough frequency to give a judgement.

4) Turbidity

Large rivers are subject to turbidities in higher ranges than is usually found in smaller feeder streams.

Large rivers also create more erosion. The soil along its course is often silt and clay. Over the centuries the hills erode towards the valley and the river. Changes in river course and velocity erodes these silts and clays into the river with the resulting increase in turbidity.

In the case of the Connecticut River Valley, agricultural activity along the river banks causes run-off from plowed fields. This adds to the material suspended load.

The many dams along the Connecticut from Turners Falls north to Vernon, Bellows Falls Dam, Wilder Dam, and seven other dams along the northern route of the river towards Canada, cause individual impoundments to fluctuate during and after power generation. River bank storage water drains from these pools during drawdown and carries sand, silt and clay into the river.

The turbidity (JCU) also varies with the flow. At the Vermont Yankee Nuclear Power monitor station No. 3, some 3,000 feet below Vernon Dam and some 11.0 miles above the Northfield diversion point, the turbidities reach above 80 JCU during spring and fall run-off. The intake for the Vermont Yankee Monitor Station No. 3 is located some 9 feet below the normal river elevation and in the main river channel as determined by a river cross section survey. It may be assumed that turbidity would increase with river depth, especially where soil particles are involved.

The turbidity records from Massachusetts Department of Public Health, taken at Northfield during 1970, showed turbidities during the February 4 to February 22, 1970, high river flows (17,000 - 37,316 cfs) ranging from 10.4 - 19.4 JCU.

During March 26 to April 30, 1970, when the Connecticut River flows were 17,000 - 74,000 cfs, the turbidities ranged from 16 to 98. The highest reading was on April 29, 1970, with a river flow of 64,000 cfs and a turbidity reading of 98.

The turbidity ranges during May 1 to May 24 were 5 - 87. The reading of 87 occurred on May 6, with a river flow of 38,600 cfs. On May 21, 1970, with a river flow of 31,041 cfs, the turbidity had dropped to 5.

The total possible diversion days during the wateryear October 1969 to September 30, 1970, was one hundred and two days, the largest diversion period for the past 10 years.

Turbidities during the wateryear October 1970 to September 30, 1971, show much lower turbidities. There were 55 days of possible diversion in this period.

The following Tables show the turbidity data taken from the records of the Massachusetts Department of Public Health and Webster - Martin, Inc., Burlington, Vermont, for the years 1968, 1969, 1970 and 1971.

TABLE G-5

WEBSTER - MARTIN, INC. ANALYSIS DATA

Vermont Yankee Nuclear Power Company
Station No. 3
North of Massachusetts State Line

Date	Montague City River Flow (cfs)	Turbidity (JCU)
01/01/68	6,000	58
01/07/68	3,500	48
01/18/68	8,000	55
01/25/68	7,000	34
01/31/68	8,100	12
02/01/68	8,100	12
02/15/68	9,500	11
02/25/68	2,700	12
03/02/68	8,000	12
03/17/68	7,970	16
03/18/68	25,700	38
03/19/68	42,300	52
03/21/68	50,000	49
03/30/68	52,700	31
04/01/68	45,300	28
04/18/68	24,100	18
04/30/68	22,700	27

May - June Records

TABLE G-6

MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH
CONNECTICUT RIVER ANALYSIS
NORTHFIELD, MASSACHUSETTS

Grab Samples

Date	Montague City River Flow (cfs)	Turbidity (JCU)
01/07/69	10,000	38
01/29/69	10,500	5
02/05/69	11,000	2.8
02/12/69	10,000	9.2
02/19/69	9,100	7.4
03/26/69	30,400	46
04/02/69	20,200	3.8
04/16/69	77,400	40.2
04/23/69	95,500	16.2
04/30/69	61,500	8.0
05/07/69	31,300	22.0
05/14/69	35,900	2.2
05/21/69	33,600	2.2
06/04/69	11,100	2.0
06/11/69	11,200	1.0
06/18/69	14,400	7.6

TABLE G-6 (cont'd)

MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH
CONNECTICUT RIVER ANALYSIS
NORTHFIELD, MASSACHUSETTS

Grab Samples

Date	Montague City River Flow (cfs)	Turbidity (JCU)
01/07/70	13,000	3.8
01/16/70	10,500	1.0
01/21/70	8,000	4.8
02/06/70	30,749	10.4
02/12/70	32,525	19.4
02/19/70	21,000	10.6
02/26/70	13,484	8.6
03/04/70	12,000	15.4
03/12/70	11,000	4.6
03/19/70	10,500	56.0
03/26/70	18,000	7.0
04/08/70	40,000	16.0
04/22/70	72,000	52.0
04/29/70	73,000	98.0
05/06/70	46,000	87.0
05/13/70	15,600	5.0
05/21/70	17,500	5.0
05/27/70	15,100	5.0
06/04/70	11,100	5.0
06/17/70	3,850	5.0

TABLE G-7

COMPARISON OF TURBIDITIES AT NORTHFIELD
(MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH)
AND
STATION #7 UPPER END VERNON POOL
(WEBSTER MARTIN DATA)

1970 & 1971

Turbidity (JCU)

Date	Flow cfs Montague City	Mass. Dept. Public Health	Vt. Yankee Station #7
03/04/70	12,000	15.4	20
03/12/70	11,000	4.6	20
03/19/70	10,500	56.0	20
03/26/70	18,000	7.0	24
04/08/70	40,000	16.0	24
04/22/70	72,000	52.0	72
04/29/70	73,000	98.0	50
05/06/70	46,000	87.0	40
05/13/70	15,600	5.0	
05/21/70	17,500	5.0	
05/27/70	15,100	5.0	16
	U.S. Army		
04/05/71	28,719*	4.4	10
04/12/71	33,040	6.8	9
04/26/71	45,600	3.4	
05/03/71	46,800	4.2	
05/10/71	52,060	8.6	
05/17/71	35,200	0.8	18
05/29/71	19,400	1.6	6
06/07/71	11,250	3.0	2

During the diversion period, April 3 to May 28, where cfs flows ranged from 17,200 to 66,880, the turbidity ranges were as follows:

TABLE G-8

MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH DATA
AT NORTHFIELD, MASSACHUSETTS

April 5, 1971 - June 7, 1971

Date	River Flow	Turbidity (JCU)
04/05/71	28,719	4.4
04/12/71	33,040	6.8
04/26/71	45,600	3.4
05/03/71	46,800	4.2
05/10/71	52,060	8.6
05/17/71	35,200	0.8
05/29/71	19,400	1.6
06/07/71	11,250	3.0

The review of this available data indicates that there is no sure way of predicting the turbidity of the Connecticut River at Northfield, based on river cfs flows. The range of units may be from 3 to 100. It appears that the turbidities may be influenced by the following general factors:

(1) Intensity of run-off caused by:

(a) Air temperature as applied to snow melt

(b) Intensity and frequency of rainfalls and available soil moisture at the time of rainfall

(2) The velocity of the river and flow

(3) Number of times the river has reached scouring velocities

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(4) The fluctuation and discharges from the upstream power pools

(5) Industrial wastes in the river

(6) By-passing of municipal combined sewers flow from primary treatment plants

(7) Degree of construction on the watershed

The review of analysis from the Vermont Yankee Monitors at Station #7 located at the northerly end of the Vernon Pool and that of Station #3, below Vernon Dam suggests that high turbidities are occurring from Brattleboro north as indicated by the high values at the upper end of the Pool. The high turbidities at Station #3 suggest that the velocity of water through the turbines for power generation at the Vernon Dam and the velocities below the Dam cause turbidities in the high range up to 100 JCU.

The lower turbidities at the Turners Falls Pool in the Northfield area indicate that some of the turbidity has settled out and would only come into "solution" again when the river velocity increased to "lift" it into suspension.

Analysis also shows that the same turbidities do not occur with the same flows, although it appears high turbidities usually occur with sudden high flows over 25,000 cfs, while a steady slow increase in flow does not cause rapid increase in turbidity.

The rapid rise in flow and its increase in turbidity is probably due not only to lifting of the river sediments but also to soil erosion and the transportation of accumulated debris over the ground surface and into the river.

In summary, it can be said that river turbidity intensity is a variable and relatively uncertain. The causes of increases are tied to environmental factors such as temperature causing increased snow melt, time of year, percent of soil moisture, intensity of rainfall and its corresponding run-off, percentage of bare soil exposed to erosion, construction intensity, soil type, and farming activity along the run-off routes, and the concentration and quality of discharge from upstream pollution sources. Thus anticipating given turbidities from a river is not possible to calculate, on a season to season basis or at the time of proposed diversion.

5) Microbiological

Coliforms: Surface water allowable 10,000/100 ml

The presence of large numbers of coliforms in the Connecticut River (20,000 - 106,000) during summer flows indicates sources of raw sewage discharges upstream from the sampling station at Route 10 and Route 142 bridges. The presence of large dairy farms to the south of this station (downstream) would probably increase the coliforms still further at Northfield in the summer. With dilution, by excess waters in the spring, there might be increases in the coliform and fecal counts, especially if sampling stations were established on the east side of the Connecticut River at Northfield at the diversion point.

The coliform count average about 2,000/100 ml during spring flows with an occasional count of over 7,000/100 ml.

TABLE G-9

NEW ENGLAND RESEARCH, INC.
COLIFORM ANALYSIS RESULTS

Date	Montague City River Flow (cfs)	Coliform	Fecal
*Caldwell Road			
04/25/70	14,050	2,300	60
05/02/70	49,275	1,090	0
06/04/70	11,100	800	0
06/11/70	10,100	17,000	2,250
06/19/70	6,070	72,000	
*Munn's Ferry			
05/02/70	49,275	2,650	70
05/06/70	38,600	1,200	0
06/04/70	11,100	4,000	150
06/11/70	10,100	19,000	15,000
06/19/70	6,070	16,500	
*Below Diversion Canal			
05/06/70	38,600	1,050	0
06/04/70	11,100	920	630
06/11/70	10,100	20,500	1,350
06/19/70	6,070	48,000	

*Caldwell Road - Just off the west bank of the river and just downstream of the Central Vermont R. R. Bridge.

*Munn's Ferry - East shore of the river, south of Merrian Brook.

*Below Diversion Canal - East shore of the river below Four Mile Brook.

TABLE G-10

MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH
COLIFORM ANALYSIS RESULTS

Route 10 Bridge - About 5 miles north of the Northeast Utilities diversion point

Date	Montague City River Flow (cfs)	Coliforms 100 ml
02/06/70	30,749	2,000
02/12/70	32,525	2,100
02/19/70	21,000	3,400
02/26/70	13,484	2,100
03/26/70	18,000	1,800
04/08/70	40,000	1,400
04/22/70	72,000	2,200
04/29/70	73,000	2,000
02/02/71	8,285	5,800
02/22/71	10,625	2,100
02/23/71	11,500	2,100
03/01/71	12,500	1,500
03/10/71	11,500	3,600
03/19/71	17,200	1,100
03/25/71	11,165	1,400
03/31/71	12,037	1,400
04/05/71	*28,719	1,000
04/12/71	33,040	700
04/26/71	45,600	7,600
05/03/71	46,800	900
05/10/71	52,060	1,700
05/17/71	35,200	2,100
05/24/71	19,400	1,400
06/07/71	11,250	1,300

TABLE G-10 (cont'd)

MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH
COLIFORM ANALYSIS RESULTS

Route 142 Highway Bridge - About 7.9 miles upstream of the diversion point
Northfield, Massachusetts

MF/100 ml

Date	Montague City River Flow (cfs)	Coliforms	Fecal
08/20/69	9,840	4,700	1
09/16/69	7,530	5,300	--
10/07/69	5,520	4,400	160
11/04/69	8,810	35,000	85
12/09/69	13,500	6,000	380
04/07/70	24,600	1,800	20
05/05/70	41,100	2,500	80
06/06/70	10,800	20,000	240
07/15/70	4,430	12,000	35
08/04/70	3,600	82,000	--
09/01/70	3,830	7,700	0
10/06/70		20,000	75
11/03/70		4,000	44

The above results indicate that much untreated sewage is discharged to the Connecticut River. The higher dilutions from high flows in the spring reduce the concentration of organisms. The volumes of industrial wastes could also inhibit growth or result in some die-off. In any event, the results of the examinations indicate the presence of diluted raw sewage from upstream sources.

6) Inorganics

Inorganics are a group of chemical compounds usually lacking the carbon element with the exception of carbonates and cyanides. Their presence in water is limited. They may affect man either as a toxic substance or in the palatability of the water due to concentration.

a) Alkalinity (Maximum Limits to 500 mg/l)

The concentration of alkalinity as Ca CO_3 ranges from 16 - 32 mg/l over the first 6 months of a year. Somewhat higher concentration of 30 - 40 mg/l in early to late fall are the general rule.

Alkalinity in the upper Connecticut River from Gilman, Vermont south to Barnet, Vermont, shows alkalinity about 20 mg/l, which may be considered normal background for the river.

b) Arsenic (EPA* Limit .05 mg/l)

Samples to date show arsenic level from .01 - .1 mg/l.

c) Barium (EPA* Limit 1.0 mg/l)

.007 - .020 mg/l

Above information from Massachusetts Water Pollution Control 1962 - 1968 data.

d) Boron (Limit 1.0 mg/l)

To date, not analyzed for.

e) Cadmium (Limit .01 mg/l)

To date, analysis shows concentration of $<$.001 - .007 mg/l with .004 during the spring run-off.

f) Chlorides (Limit 250 mg/l)

Concentration is influenced by the snow and the ice melt intensity and the amount of salt used on highways. It also depends on the discharges from upstream pollution sources, the square feet of highway surface in the watershed adjacent to the River.

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*E.P.A. - Environmental Protection Agency - Surface Water Permissible Criteria

The highest concentration of 12.4 mg/l recorded by the Massachusetts Department of Public Health occurred on March 26, 1970. The lowest concentration of 3.8 mg/l occurred on May 6, 1970. The summer high value was 12.4, which occurred July 1, 1970, and may be due to municipal or industrial discharges.

In 1971, to date, chlorides have a range from 5.0 mg/l on April 26 to a high of 21.6 mg/l on January 6. During spring run-off, the average was between 10.0 - 12.6 mg/l.

g) Chromium Hexavalent (max. 05 mg/l)

Analysis by Webster-Martin, Inc., Burlington, Vermont, showed concentration at Northfield of .019 with a max. of .06 recorded on November 28, 1969. These appear to represent an industrial "dump." The majority of analysis showed zero chromium.

Storet Data 01/01/65 - .006 with an average less than .002 from 1962 - 1968.

h) Copper (EPA Limit 1.0 mg/l)

Concentration of copper ranges from 0 on analysis, September 16, 1969, to .010 on September 1, 1970 (2 samples only). Massachusetts Water Pollution Control and Webster-Martin, Inc., Burlington, Vermont, recorded concentrations of .05 - .07 mg/l at Northfield with a high of .08 mg/l at their Station #3, 11 miles upstream of Northfield Intake.

Storet Data show ranges from .011 mg/l to .021 mg/l (1962).

i) Dissolved Oxygen (Recommended to be as high as possible at Northfield)

During the spring run-off period, concentrations range from 10.0 - 13.8 mg/l and drop to 5 mg/l during the summer months.

During the low, Connecticut River flows of 1965, the D.O. dropped to 2.2 mg/l on April 26, and to 4.6 mg/l on May 3. The river flow on April 26, 1965, was 18,900 cfs and on May 3, 1965, 16,200 cfs.

The low D.O. would suggest a high B.O.D. or C.O.D. either from an upstream pollution source or from the scour of the river.

A high D.O. will be necessary during diversion periods. The water added to Quabbin may be stratified by early May. Thus, a higher concentration of 0_2 in the water in the hypolimnion is needed to meet the B.O.D. and C.O.D. demands.

The Connecticut water has a high C.O.D. value and a probability of a higher B.O.D. than is indicated by a B.O.D.$_5$. The oxidation of ammonia to nitrates probably is not reflected in the B.O.D.$_5$; therefore, high oxygen values are required to maintain minimum oxygen values, especially for Iron, Sulfate and Manganese Control.

j) Fluorides (Limit .8 - 1.7 mg/l)

Surface waters in Massachusetts are low in fluorides - .20 mg/l in most cases.

Fluorides in adequate amounts appear in some drilled wells only.

k) Hardness (Limits of general public max. tolerance 300± mg/l)

During spring run-off, the hardness ranges from 14 - 50 mg/l, with a general average of 32 mg/l.

l) Iron (EPA Limit .3 mg/l)

Analysis by the Massachusetts Department of Public Health in 1970 shows iron varying from a high of 1.55 mg/l to a low of 0.24 mg/l during the general diversion period of that year, February to May. The average was .72 mg/l during the 102 possible diversion days.

Massachusetts Department of Public Health Analysis for the period April 5 to June 7, 1971, shows a max. of .47 and a low of .19, with a mean of .37 mg/l. There were 55 possible diversion days during 1971.

In 1969, upstream from the Massachusetts sampling station at the Route 10 Bridge, and Station Monitor #3, Vermont Yankee Nuclear Power shows a max. iron of 3.4, on July 31, 1969, a low of .10 on May 22, 1969. The mean of all samples collected was .62 mg/l. During this period, there were 86 diversion days.

The results of a sample analysis collected by the Environmental Protection Agency on April 6, 1971, (River Flow at Montague City, 27,719 cfs) shows an iron concentration of 1.0 mg/l.

The analysis indicates that as flow increases and diversion time increases in the River, the concentration of iron increases.

The 1969 records of analysis from Massachusetts Department of Public Health show a max. iron of 3.2 mg/l and a low of .10 with a mean during the diversion period of 1.24 mg/l over the diversion period from March 26, 1969 to May 21, 1969.

m) Manganese (EPA Limit .05 mg/l)

Analysis made by Massachusetts Department of Public Health in 1969 shows a high value of .26 mg/l and a low of .00 with a mean of .14 mg/l.

The 1970 Massachusetts Department of Public Health analysis figures show the following:

High .32 mg/l
Low .00
Mean .13

The 1971 analysis shows:

High .22
Low .08
Mean .14

The above figures cover the general diversion periods when Connecticut River water could be diverted to Quabbin Reservoir.

n) Nitrates (NO_3) (EPA Limit 10 mg/l as N)

The concentration of nitrates from Massachusetts Department of Public Health Laboratory analysis shows the following concentrations during diversion flows:

Year	mg/l High	Low	Mean	Total Diversion Days
1969	.51	.26	.33	86
1970	1.75	.11	.66	102
1971	.56	.37	.46	55

The 1.75 mg/l of NO_3 occurred when the river was at its peak flow for the period, 73,000 cfs at Montague City.

o) pH (Desirable Limits - Massachusetts Quality Standards for Class B Water 6.0 - 8.5 mg/l)

The range of pH is 6.7 - 7.0 during proposed diversion flows with an average of 6.9 at Northfield in 1970. In 1971, the average for the diversion period was 6.8. The above data are from grab samples. The analysis from a continuous monitor at Station #3, Vermont Yankee Nuclear Power Corp., some 11.7 miles above Northfield shows the following:

	1969	1970	1971
March Range	6.8 - 7.3	6.6 - 6.8	6.2 - 6.4
April Range	6.7 - 7.4	6.6 - 6.8	6.3 - 6.7
May Range	no data available	6.6 - 7.1	6.5 - 6.7

p) Phosphorus (Limits not established desirable .01 - .03 mg/l)

Massachusetts Department of Public Health Data

Year	mg/l Max.	Min.	Mean	Diversion Days
1969	.79	.10	.23	86
1970	.30	.12	.22	102
1971	.31	.03	.13	55

The concentration of phosphorus is above that recommended for the control of algae and aquatic growths.

q) Selenium (EPA Limit .01 mg/l)

No Records Available.

r) Silver (EPA Limit .05 mg/l)

Available data from Storet Retrieval, October 1962, to June 1968 shows a range of .001 to .004 mg/l. One sample collected April 6, 1971, had a value of .002 mg/l. No data available after this date.

s) Sulfate (EPA Limit 250 mg/l)

The concentration of sulfates ranges from 5.0 - 13.0 mg/l and a mean of about 12 mg/l. Sulfates show an average increase of 6 mg/l since 1962.

t) Zinc (Limit 5 mg/l)

The range of zinc from Storet Retrieval Data, 1962 to 1968, shows a high of .69 mg/l in July 1964, and a low of .020 mg/l in April 1967. One sample collected April 6, 1971, had a value of .04 mg/l.

7) Organics

Organic compounds contain carbon and are derived from plants and animals, but not limited to these species. Many compounds are produced by synthesis.

In general, organics are usually combustible, have low melting and boiling points, are usually less soluble in water than inorganics. Usually, organic compounds are slow in reactions, and most are food for bacteria and other organisms.

Organics play an important role in their effects on man and how these substances react in diluted solutions.

a) Carbon Chloroform Extract (Limit 0.15 mg/l)

The concentration ranges from .058 mg/l to .159 mg/l with a mean since 1962 of .087 mg/l.

b) Cyanide (Recommended level .01 mg/l)

.02 mg/l recorded in September 1970 at Northfield Station.

The presence of cyanide in the River of .02 mg/l indicates a "dump" of cyanide from some industrial plant upstream.

c) Oil, Grease and Gasoline

Present from time to time from upstream sources. Oil and gasoline are stored along the Connecticut River, south of Brattleboro, Vermont. This is a potential source. Industrial plants on the Ashuelot River and other industries in and about Brattleboro are also potential sources.

d) Pesticides

Aldrin, Chlordane, DDT, Dieldrin, Endrin, Heptochor, Heptochlor epoxide, Lindane, Methoxychlor, Organic phosphates, Carbomates, Toxaphene.

Concentration of these materials are well below limits established by the U. S. Public Health Service and Environmental Protection Agency.

e) Herbicides (2.4D, 2.4.5-T, 2.45 T-P)

Concentration is as either absent or well below the limits set by the U. S. Public Health Service and Environmental Protection Agency.

f) Phenols (Data not available)

g) Radioactivity

Gross Beta (max. 1,0000 allowable)
Connecticut River shows 1 - 3 pc/l.

B. Quabbin Reservoir

1) Description

The Quabbin Reservoir was created in the Swift River Valley by the construction of two large earth dams with concrete core walls. The main dam (Winsor Dam) is 2640 feet long and 170 feet high. The second dam, known as Quabbin Dike, is 2140 feet long and 135 feet high.

The Reservoir impounds the run-off from 186 square miles of the Swift River watershed plus an average of about 10×10^9 diverted waters from the 96 square mile Ware River watershed.

The filling of Quabbin Reservoir began in August 1939, and on May 30, 1946, the water had reached the elevation of the spillway stop logs at elevation 528.00.

The Quabbin watershed comprises a heavily wooded area with sparce human population. There are no industries on this watershed or sources of pollution. Industries and homes were brought and removed as part of the water quality program adopted by the MDC in the early 1930's. There are ample populations of wildlife including deer, wildcat, otter, beaver and birds of prey and some eastern coyotes. The deer population has

decreased over the past 22 years due to the limits on their winter food supply. In 1947, there was one deer/19.7 acres. In 1949 - one deer in 53 acres.

The Ware River Watershed comprises 96 square miles and is more populated and less under strict Metropolitan District control. This watershed is open to hunting, recreation and unrestricted fishing and is less restricted on building and general construction. The only municipal sewerage system on the Ware Watershed is in the Town of Rutland. Dwellings remaining on the Quabbin Watershed are all on individual sewage systems.

The water of Quabbin Reservoir supplements the supply at Wachusett Reservoir some 24.6 miles east.

The water from Quabbin is conveyed to Wachusett Reservoir by a horseshoe shaped tunnel with a cross-section equivalent in area to a circle of 12 feet, 9 inches in diameter.

2) Quabbin Volume (Elevations are Boston Base, not U.S.G.S.)

The full reservoir volume of Quabbin at elevation 530.00 is 412 billion gallons. This elevation and volume has not been reached since May 1, 1961.

A low elevation was reached on March 1, 1967, at an elevation of 495.80. Since that time, the pond elevations have been fluctuating between elevation 500.00 and 511.00.

The elevation on January 1, 1972, was 500.37. It would appear that the Reservoir elevation is about three feet lower than that on January 1, 1971.

At elevation 500, there is about $208.3^{+}_{-} \times 10^{9}$ gallons in storage. At elevation 490.00, the volume is approximately 157.0×10^{9} gallons.

The intake to Wachusett Reservoir is located at Shaft 12, with two available drawing depths, the lower opening at 456.25 and the upper openings at 481.75. The stop-logs can be adjusted for a lower intake to elevation 428.00. However, at this elevation, there is only 9.9×10^{9} gallons remaining in the Reservoir and is unavailable for draft.

At Elevation 480.00, much of the Middle Branch of the Reservoir would be dry or about 14,000 acres over the entire Quabbin Reservoir area would be in real estate. Only the old or small river valleys would have any amount of the water below this elevation.

Quabbin Reservoir is made up basically of two main branches or arms. However, for general consideration, there is a third branch at the extreme east side. This branch is very shallow, much of the area is at elevation 510 - 530.00, and was dry on January 1, 1972, except where the water is stored behind a regulating dam.

Therefore, the main investigation involves the middle branch and west branch.

This study covers the physical and chemical conditions that exist in these areas. The diversion from the Connecticut River, the Tully or the Millers Rivers would enter either the middle branch, west branch or both.

The west branch and middle branches are separated by Prescott Peninsula, a tongue of land some 9 - 10 miles long and averages 2 - 2.5 miles wide. At this southerly end, the two branches are joined by a narrow channel, about one mile long and varies some 2,000 to 3,000 feet in width.

The west branch has depths ranging from 55 feet at its northerly end to 130 feet at the southerly end near the end of the Prescott Peninsula. The west branch averages about 3,000 - 4,000 feet in width. The slopes are very steep and is typical of an oligotrophic lake - low in macroscopic production and higher in oxygen in the hypolimnion layer than the other branches.

The middle branch is shallow (less than 50 feet over large areas) at its upper-half with a width of over 2 miles. Its large surface and shallower depth lends itself to eutrophic conditions conducive to aquatic production.

Much of the submerged areas are sandy. Vast areas, by observation above elevation 500 to 530, contain unconsolidated sands and gravels.

There are many islands and large areas of shallow water between deep pockets.

3) Stratification of Quabbin Reservoir

Quabbin Reservoir develops thermal stratification as does most large deep bodies of water. Bodies of water in New England during the general period from April through October develop temperature stratification. The stratification of a body of water involves three temperature zones. The top layer of water from surface to depth of 20' - 30' is known as the epilimnion. The second or middle layer is called the thermocline. In this zone, the temperature shows a sharp drop in depth. This layer is

shallow, usually ranging in depth from 10 - 15 feet. Below this layer is the zone called the hypolimnion. This region is usually below 40 feet in depth and extends to the bottom of the reservoir. The zone has little or no contact with the surface and is, therefore, lower in temperature and low in dissolved oxygen. Reservoirs that are eutrophic (biologically productive) may have no dissolved oxygen in this zone. Reservoirs that are oligotrophic (biologically unproductive) have ample dissolved oxygen, usually above 3 mg/l. During very warm still days that may occur in April or early May, thermal stratification will begin. Each year, due to climatic conditions, stratification will form. The beginning and end of this condition varies with the particular year.

Limited temperature studies show that, in general, stratification is established first in the upper Middle Branch of the Reservoir. In 1970, studies showed that in June, the upper middle branch had a thermocline established at 34 feet. The thermocline depth in the west branch was recorded at 25 feet.

As a general statement, it can be stated that the middle branch is warmer in the spring by a range of 3^{o} - 7^{o}F at depths to 15 feet in relation to the west branch.

In the fall, September and October, evidence shows the middle branch to cool earlier and a break-up of the thermocline at an earlier date than the west branch.

The Dissolved Oxygen in the middle branch ranges from 9.0 mg/l in June at the surface to a low of 4.0 at depths of 70 feet.

Since 1961, the dissolved oxygen in the hypolimnion zone has decreased from a high of 7.0 - 10.00 mg/l to 4.0 - 5.0 mg/l in 1971. There are too few stations and analyses to determine this true meaning. Based on the available data, the oxygen loss indicates that as the reservoir decreases in elevation, the volume of water of the hypolimnion is also decreased because the epilimnion and thermocline tend to have the same depth. Therefore, the pounds of oxygen available in the volume of the hypolimnion remaining is less to meet the Bio-Chemical Oxygen Demands. The final concentration of available oxygen at the end of the year in relation to the demand is, therefore, less.

In the upper layer, epilimnion and thermocline zones of the middle branch, the oxygen concentration is slightly higher than the west branch. This is a result of a larger surface area and volume available for oxygen entrainment.

The west branch oxygen concentration in the hypolimnion ranged from a high of 7.0 - 10.5 in 1961 to a low of 5.3 - 7.7 in 1971.

It appears that the oxygen demand is less on the west branch. The fact that the branch is oligotrophic accounts for this value.

4) Temperature Differences of Connecticut River and Quabbin Reservoir

The dilution and mixing of the river water and reservoir water and the travel through the reservoir depends to some degree on the temperature differentials of the two waters.

A water supply reservoir in Tacoma, Washington, has experienced numerous short-circuiting instances where a temperature differential of 3^{o} F resulted in the river water traveling through the reservoir to the water supply intake.

The investigation of Connecticut River temperatures and the temperatures of Quabbin during the diversion period have a strong bearing on the discharge volume and location of the discharge to avoid or reduce short-circuiting, and to provide dilution and mixing of the lower quality water of the Connecticut. Therefore, Quabbin stratification and temperature in these stratified zones play a vital role in the resultant water quality.

The following tables listed are far from complete in desired information of temperatures that exist in the east and west branches of Quabbin.

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TABLE G-11

QUABBIN STRATIFICATION

1969

Temperature (Fahrenheit)

Depth (feet)	April 17 Sta 2	April 17 Sta 4	May 1 Sta 2	May 1 Sta 4	June 18 Sta 2	June 18 Sta 6	June 18 Sta 11	July 15 Sta 2	July 15 Sta 6	July 15 Sta 11	May 28 Sta Not Known
0	49.5	45	50	48	70.1	70.0	72	76.2	75.9	74.8	56
5	49.5	45	50	48	70.5	70.5	71.8	74.1	72.9	72.1	56
10	44	44.5	50	48	70.6	70.5	71.4	73.0	72.2	71.9	55
15	44	44	49.5	47.5	70.6	70.4	71.0	72.8	71.8	71.8	55
20	44	44	49.5	46.5	71.2	70.2	70.5	72.5	70.5	71.8	55
25	44	44	49.5	46.0	69.4	70.1	69.9	72.1	69.7	71.8	55
30	44	43.5	49.5	45	68.0	70.0	66.0	71.2	66.1	71.9	55
35	44	43	49.5	44.5	66.5	65.0	64.9	65.8	64.7	64.2	54
40	43.5	43	49.0	49.5	64.9	61.0	62.5	61.0	61.9	63.0	53
45	43	43	48.5	44.5	63.0	59	60.0	59.3	59.9	60.1	52.5
50	43	42.5		44.0	62.2	58	59.0	58.0	58.1	59.2	52
60	43	42	47.0	44.0	61.0	57	57.0	57.0		56.9	51
70	43	42	46.5	44.0	59.8		55.1	54.8		56.0	50
80	43	42	46.0	44.0	58.4			53.2			47
90	43				57.0			51.7			
100	43				56.0			51.2			
110	42										
Average Conn. River Temp. that day	43.2		46.9		70.4			74.0			59.7

General Diversion Period
Monthly Raise in Temp.

	Apr 1 - 30		May 1 - 31		June 1 - 30		July 1 - 31	
	Min	Max	Min	Max	Min	Max	Min	Max
	32.9	47.9	46.9	61.8	63.9	72.4	73.4	73.7
Average	40.7		53.4		68.8		75.2	

TABLE G-11 (cont'd)

QUABBIN STRATIFICATION

1970

* May 2 Temperature (Fahrenheit)

Depth (feet)	May 9 Sta 2	May 9 Sta 4	May 9 Sta * 11	June 11 Sta 2	June 11 Sta 4	June 11 Sta 11	July 8 Sta 2	July 8 Sta 4	July 8 Sta 11
0	50	53	54	67	69	68	70	71	72
5	47	49	53	66	69	68	71	72	71
10	47	48	52	66	68	67	71	71	71
15	47	48	50	65	68	67	71	70	70
20	47	48	49	65	66	66	69	69	69
25	47	48	49	64	64	64	68	69	68
30	47	47	49	61	62	60	65	67	67
35	47	47	48	58	61	57	63	63	63
40	47	47	48	56	59	55	59	58	61
45	46	47	48	55	56	54	56	56	58
50	46	46	47	53	55	53	55	54	56
60	46	45	47	52	54	52	53	52	58
70	45	44	46	51	53	52	51	51	52
80	45	43	46	50	51	51	50	49	51
90					49		48		
100					48				
110					48				
Average Conn. River Temp. that day	49.4	50.8		67.4			72.3		

General Diversion Period
Monthly Raise in Temp.

	May 1 - 31		June 1 - 30		July 1 - 31	
	Min	Max	Min	Max	Min	Max
	48.3	59.2	60.2	68.7	68.9	79.5
Average	54.8		67.8		75.5	

These tables show that the temperature of the river and of Quabbin are not the same each year. The time each year is not available on the Quabbin Station. The temperatures are shown for the Connecticut River for May, June and July.

The data shows that April diverted water from the Connecticut would tend to mix well. During May, the Connecticut River water could tend to move toward the upper water layers. In June and July, the river water would tend to "ride" over the thermocline. The movement of this river water in the reservoir will, in general, be subjected to wind forces and direction.

5) Water Quality in Quabbin Reservoir's Main Feeder Streams

The total watershed of Quabbin Reservoir comprises 186 square miles of basically forested area.

The water quality management program and the initial water quality consideration used in the development of the Quabbin Reservoir consisted of the removal of the sources of pollution and potential sources of pollution. This policy required the purchase and removal of homes, farms, and industries located in the watershed area and, of course, in the area of the reservoir.

The water quality analysis studies began in preparation for the proposed reservoir in the late 1920's and early 1930's. The policy of watershed protection also involved the Ware River watershed, but to a lesser degree of property removal. The result of this policy has been the production of a finished high quality water in Quabbin Reservoir. As an evaluation of the "treatment" effect of Quabbin by dilution and storage of the feeder stream waters, it is necessary to review the quality of these streams as a background of information in the appraisal of physical and chemical quality of the finished water leaving Quabbin Reservoir at Shaft 12 drafting point.

The main feeder streams of the Quabbin watershed are:

(1) West Branch Swift River
(2) Caldwell Brook
(3) Middle Branch Swift River
(4) Hop Brook
(5) East Branch Fever River
(6) East Branch Swift River

The above main feeder streams comprise about 82 square miles of the 186 square miles of the entire drainage area of Quabbin Reservoir.

The following table shows the available MDC data of the quality of these streams:

TABLE G-12

WATER QUALITY OF FEEDER STREAMS

Maximum and Minimum Values

Stream	JCU Turbidity	S Units Color	mg/l Chlorides	mg/l Alkalinity	pH	mg/l Iron	per 100 ml Coliform
West Branch	.9	21	6.3	5.9	6.8	.17	680 (1956)
Swift River	.4	12	2.0	3.8	6.2	.05	16 (1968)
Caldwell	1.0	20	5.1 (1969)		6.3	.07	670 (1956)
Brook	.3	10	1.8 (1956)		6.0	.04	52 (1968)
Middle Branch	1.1 (1957)	41	7.4 (1970)	7.9	6.3	.29	580
Swift River	0.6 (1970)	29	2.2 (1958)	5.5	5.9	.10	14
Hop Brook	1.1	24	8.5 (1966)	8.9	7.3	.20	800
	0.5	13	3.1	7.1	6.4	.06	14
East Branch	1.4	84	12. (1970)	4.6	6.0	1.0	180 (1956)
Fever River	.7	26	2.6 (1956)	3.0	5.4	0.23	41
West Branch Fever River (1970 only)	.08	80	9.7	7.0	6.3		10
East Branch	1.5	62	8.3 (1970)	6.6	6.6	.80	470
Swift River	0.9	35	2.9 (1956)	4.2	6.3	.17	10

TABLE G-13

WATER QUALITY AT SHAFT 12 INTAKE FROM QUABBIN RESERVOIR

8 Year Record
1963 - 1970

Turbidity (JCU)

Maximum	.7 (1965)
Minimum	.4

Color (Units)

Maximum	6
Minimum	5

Chlorides (mg/l)

Maximum	4.6
Minimum	2.4

Alkalinity (mg/l)

Maximum	5.6
Minimum	4.0

Hardness (mg/l)

Maximum	11
Minimum	9

Iron (mg/l)

Maximum	.15
Minimum	.08

Coliforms (100 ml)

Maximum	9
Minimum	1

The average turbidity of all seven of the main feeder streams flowing into Quabbin since 1956 was .80 JCU. No calculations were used to apply turbidity to the flow of that period. For example, a stream might have a turbidity of 1.0 while flowing 10 cfs and a .5 while flowing at 1 cfs. Applying equal weight, the average would be .75 average. To calculate the resultant turbidity from a stream, based on flows vs. turbidity, would be too time consuming and meaningless based on those low values. Therefore, giving equal weight to each unit is a relative guide to the turbidity relationship between the feeder streams and the resultant water quality leaving Quabbin.

The average turbidity at Shaft 12 intake is 0.50 Jackson Candle Units. This is a 38% reduction based on the feeder stream averages only. In all the turbidity analyses, no distinction was made to the kind of turbidity in the stream as compared with the kind of turbidity at Shaft 12.

The average color of the seven major streams flowing into Quabbin, including the Ware River diversion, is 35 S. units, also given equal weight to each stream. The net reduction in color at Shaft 12 to 6 units determines there is a reduction in color. The increase in chlorides for 1956 to 1970 is due to the increased use of sodium and calcium chloride on the highways.

The small variation in alkalinity would indicate stable conditions on the watershed. This also applies to pH and hardness. The reduction in iron of 300 - 400% is the result of oxidation of ferrous form to the insoluble ferric hydroxide as shown in this equation:

$$4\ Fe\ (HC\ 0_3)_2 + 2H_20 + 0_2 = 4\ Fe\ (OH)_3 + 8CO_2$$

If the pH is neutral or above, iron is precipitated rapidly. When the water is more acid, the reaction is slower, with an increase in turbidity.

The iron precipitated as FeOH will disassociate to a ferrous ion when the following conditions are present:

(1) the water is nearly free of 0_2

(2) the pH is less than 7.5

(3) the water contains adequate amounts of CO_2

(4) organic substances are present to reduce the ferric hydroxide

Therefore, as long as the 0_2 remains above zero with a minimum of organic matter, the iron present in the hydroxide form will not go into solution.

The dissolved oxygen concentration in the hypolimnion, 12,000 feet west of Shaft 12 on October 1, 1971, was 4.0 mg/l at 70 feet of depth. The low oxygen demand in Quabbin to date has not depleted the oxygen in the hypolimnion. However, there is some limited evidence that a loss of oxygen may have occurred in September 1967 and probably did occur a month later in October at Shaft 12. This is shown in a rise in iron from .10 mg/l to .50 mg/l at 70 feet of depth and an increase in turbidity from 1.0 at the surface and at 50 feet of depth. Color increased from 6 units to 20 units. The estimated elevation of the reservoir at this period was about 502.

This evidence, although very limited, suggests that caution and good judgement and common sense must be employed in the discharge of high oxygen demanding water into Quabbin.

The coliform count in the feeder streams is low (100 or less), especially in the past five years. The count at Shaft 12 is less than 10.

The low coliform count reflects the excellent management program that the Metropolitan District Commission has had in operation for many years.

The long range management policy and the wisdom of men has resulted in excellent quality water, not only in coliform count, but in other parameters as well, at the least possible cost. It is doubtful that such a program technique can even again be duplicated.

6) Water Quality - Ware River

The diversion of the Ware River at Shaft 8 is limited to a period from October 15 to June 15 in any year. The diversion of water from this period is restricted to a degree by the required release of 85. x 10^6 gallons per day to the Ware River below Shaft 8. After June 15, all water flowing down the Ware at Shaft 8 must be released.

The diversion of the Ware River water to Quabbin occurs in general from March through May 15 -- the average cut-off date is about May 15.

The diversion rate may be up to 600 - 700 million gallons a day, however, at such rates the overflow at Shaft 2, Holden, Massachusetts, Quabbin to Wachusett Aqueduct, near the Quinaposset River, is high. This overflow water flows by channel to Quinaposset River and then to Wachusett Reservoir. Overflow to Wachusett could be up to 100 x 10^6 gallons/day.

The overflow rate at Shaft 2 begins when the diversion rate to Quabbin is about 530 x 10^6 gallons per day and increases with an increase in Ware River water intake at Shaft 8. Ware River water is diverted to Quabbin for quality reasons, but may be diverted for storage.

The water from the Ware watershed is highly colored with values varying from 35 - 75 units. Large volumes of this water would be unacceptable at Wachusett due to this high color. Small volumes are diverted directly to Wachusett, but are usually mixed with Quabbin water.

The aqueduct from Quabbin to Wachusett is used to draft water from Quabbin east to Wachusett and also used to divert water west from the Ware to Quabbin all by gravity. Thus, some of the Ware River water can be diverted to Wachusett along with Quabbin water.

The water diverted to Quabbin Reservoir enters the Reservoir at Shaft 11-A in the East Branch. Here the water must flow north past the Baffle Dam at Mt. Zion and along the east side of Mt. Zion and the shores of Quabbin to a point about four miles north. The water then may enter the main Middle Branch between the northern end of Mt. Zion and the southern end of Mt. L. Table presents water quality data in the Ware River.

The average diversion from 1950 - 1954 was about 8 x 10^9 gallons; from 1955 - 1960, 10.2 x 10^9; from 1961 - 1965, 8.4 x 10^9; and from 1966 - 1970, 10.0 x 10^9. The storage volume in the East Branch and in the Middle Branch is about 5.14 x 10^9 gallons at Elevation 500. The volume at Elevation 530 is about 24.2 x 10^9.

The following table shows the volumes of water diverted from the Ware River since 1962 and a comparison of the possible diversion volumes from the Connecticut River.

The ratio of diversion volumes from the Connecticut and Ware, in general, averages about 2.5 to 1 with a high year value of about 5.5 to 1 and a low value of 1.5 to 1.

TABLE G-14

WATER QUALITY

WARE RIVER AT QUABBIN AQUEDUCT INTAKE

14 Year Average

Year	Turbidity	Color	Chlorides	Alkalinity	Hardness	pH	Fe	Coliforms
1956	1.5	50	2.4	4.8		6.0	.29	130
1957	1.5	42	2.9	4.6	13	6.1	.41	43
1958	1.3	57	2.6	4.6	11	6.2	.42	300
1959	1.6	75	3.0	5.3	10	6.3	.38	120
1960	1.8	58	3.1	5.5	10	6.3	.27	690
1961	1.4	57	3.0	4.7	10	6.2	.28	114
1962	1.2	52	3.3	3.4	10	6.0	.25	26
1963	0.9	48	4.2	3.7	10	6.0	.23	30
1964	1.1	38	4.6	4.4	12	6.1	.27	23
1965	1.0	35	4.8	5.0	16	6.2	.27	32
1966	1.2	46	5.6	4.5	14	6.2	.39	12
1967	1.3	66	6.0	5.2	12	6.2	.35	53
1968	0.9	60	6.5	5.2	12	6.1	.29	21
1969	1.3	59	6.9	6.7	12	6.5	.40	40
1970	1.2	47	6.7	5.0	13	6.3	.33	61

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TABLE G-15

COMPARISON OF WARE RIVER DIVERTED VOLUMES TO THEORETICAL CONNECTICUT RIVER MAINSTEM DIVERSIONS

Year	Ware River Diversion (Actual) million gallons	Theoretical Diversion from Connecticut River to Quabbin million gallons
1962	12,747	18,000
1963	8,091	27,750
1964	10,397	24,375
1965	2,337	7,500
1966	4,632	25,500
1967	16,098	25,870
1968	12,693	31,120
1969	14,393	37,870
1970	16,732	31,120
1971	9,447	20,625

C. Proposed Diversion Outlet Location at Quabbin Reservoir

The Metropolitan District Commission has proposed an entrance into Quabbin Reservoir from Northfield Mountain at the northern end of the Middle Branch at Rattlesnake Hill.

This location is a direct route from the Mountain storage pond to Quabbin Reservoir; and from an economic point, this location might be the least expensive.

There appear to be some disadvantages at this location, however:

1) The main disadvantage of this one-way approach is the lack of flexibility. In the event that the volume of the middle branch was such that at the time of diversion the inflow from the Connecticut would equal or exceed the storage volume north of Shaft 12 or the results of the Reservoir monitor or sampling indicated a change in the quality at Shaft 12, then the only alternative would be to stop the flow from Northfield thus losing millions of gallons in storage potential.

2) Another disadvantage is the placing of nutrient and algae seeded waters from the Connecticut into the most productive area of the Reservoir.

The temperature in the upper sections of the Middle Branch warm more rapidly in the spring. The introduction of river water into a large epilimnion layer could result in a rapid bloom of algae. Such a build-up would result in taste, odor and increase in turbidity, oxygen demand and increased eutrophication with time.

3) The Middle Branch from Shaft 12 north to Rattlesnake Hill contains 169.47×10^9 gallons @ full pond (Elevation 530). At an elevation of 500.00, there is approximately 62.4×10^9 gallons, and at elevation 480, about 24.1×10^9 gallons.

Complete mixing is most unlikely under natural conditions due to temperature differentials and wind forces.

4) The Middle Branch is subject to more rapid warming during the period of diversion. Thus, stratification will occur first in this area and cause the warm river water to ride on the epilimnion layer in the first few feet depending on the stratified layer.

The amount of available temperature data on Quabbin is limited, however, based on the Connecticut River temperatures, it may be said that the months of January, February and March, the temperatures in the Connecticut range in the 32° - 33° F range. In April, a rapid rise in river temperature occurs with a monthly rise of about 15 degrees. In May, the rise in the river temperature is also about 15 degrees, and in June, about 7° - 8° F.

The evidence, therefore, indicates that in the beginning of the spring diversion period (March) the incoming water is colder that Quabbin, but warms rapidly week by week beginning in April.

It is noted that there is a wide range in temperature from year to year during the months of April, May and June. Thus, at what depths the incoming water will reside will not be consistent year by year.

5) The total volume of the Middle Branch is less than the total volume of the West Branch. Because of its smaller volume, the Middle Branch has less potential dilution and is more susceptible to short-circuiting to Shaft 12 Intake. The north and northwest winds that prevail during the early and late spring could push warm Connecticut water south towards Shaft 12.

6) The increase in organic load from the Connecticut River concentrated in one area will cause a heavy demand on the available oxygen supply, especially when the river water lies in the deeper southern areas toward Shaft 12.

The following two tables show the relative volumes with elevation in the Middle Branch of Quabbin Reservoir, north of Shaft 12, and the relative volumes with elevation in the Ware River Diversion Discharge Zone, bordered by the East Branch Quabbin, Baffle Dam, Mt. Zion, Mt. L, and easterly shore of Quabbin.

TABLE G-16

QUABBIN RESERVOIR VOLUME

MIDDLE BRANCH

North of Shaft 12

Elevation (feet)	Area (sq. ft. x 10^6)	Section Depth (feet)	Volume (cu. ft. x 10^6)	Capacity (gals. x 10^6)
530	600.7	10	5,617.1	42,015.9
520	524.7	20	8,683.1	64,949.4
500	349.6	20	5,110.4	38,225.9
480	172.3	10	1,402.8	10,493.1
470	110.8*			
460	69.3	40	1,843.8	13,791.7
440	24.3			
430	4.7			
		Total	22,657.2	169,476.0

* Interpolated between 480 and 460 values.

TABLE G-16 (cont'd)

QUABBIN RESERVOIR VOLUME

WARE RIVER DIVERSION DISCHARGE ZONE

From Shaft 11-A

Elevation (feet)	Area (sq. ft. x 10^6)	Section Depth (feet)	Volume (cu. ft. x 10^6)	Capacity (gals. x 10^6)
530	131.8	10	1,154.7	8,636.9
520	99.9	20	1,412.2	10,563.0
500	44.9	20	688.6	5,150.9
480	24.9			
		Total	3,255.5	24,350.9

A more flexible approach to distribution of Connecticut River water from the standpoint of dilution, algae and aquatic vegetation production, and over-all reduction of "stress" on Quabbin is the use of a Y where one leg would terminate in the Middle Branch, and the other leg would terminate in the West Branch of Quabbin Reservoir. The following advantages of this scheme are:

1) A large flexibility will be required because of differentials as to temperature, wind, chemical quality of the incoming water and elevation of the Reservoir that determines the dilution rates at the time of diversion.

2) The diversion of flow to two branches of the reservoir reduces the organic load and increases the potential dilution factor by 8 - 9 times, thus reduces the oxygen demand by an equal amount.

3) During the late April and May, when the river water increases in temperature and stratification begins at the Reservoir, it may to advantage to divert all or a large portion of the river water to the west branch, thereby avoiding any possibility of a direct short-circuiting to Shaft 12.

4) The west branch is not eutrophic and therefore the chances of algae blooms are much reduced. The surface area in the West Branch is far less than the Middle Branch and therefore has less area for photosynthesis.

The only disadvantage to the Y Branch is the cost of the extended tunnel or channel to the West Branch, some 3,000 feet south the northern most end of the Rattlesnake Hill.

It has been mentioned that damage would be done to Salmonidae and other fish families from 0_2 loss in the hypolimnion during stratification in the West Branch. However, oxygen loss should not occur when the "Class B" water of the Connecticut is properly distributed through both branches.

D. Connecticut River Sources of Pollution North of the Northfield Pump Storage Facilities Diversion Point

1) New Hampshire - Ashuelot River

The Ashuelot River is a major source of pollution to the Connecticut River and Quabbin Reservoir. At the beginning of any proposed diversion, in March or April, between 6% and 12% of the flow of the River at

Northfield is from the Ashuelot River. At the later part of the diversion period in late May or June, it represents about 2% - 12% of the flow at Northfield.

Studies conducted by the U. S. Public Health Service as far back as 1950 - 1954 and F. W. Q. A. studies in 1965, and Webster & Martin studies in 1966, indicate that the river is a major source of industrial and municipal wastes. During 1971, a sanitary survey was conducted on this river from Keene, New Hampshire, to the confluence with the Connecticut River.

The following are the major point sources of pollution on the main stem Ashuelot River:

(1) Keene, New Hampshire - Partially settled municipal wastes enter the Ashuelot at the confluence of the West Branch Ashuelot with a maximum discharge of 8 mgd.

(2) Homestead Woolen Mills, West Swansey, New Hampshire

(3) Town of Winchester, New Hampshire

(4) Lawrence Leather (Swift and Company) Winchester, Mass.

(5) Paper Service Mills, Inc., Winchester, New Hampshire

(6) Ashuelot Paper Company, Ashuelot, New Hampshire

(7) G. E. Robertson Paper Company

(8) Concel, Inc.

(9) Town of Hinsdale

The net result of this massive volume of partial or untreated municipal and industrial wastes is a river water that no longer resembles water. The color of the river water varies with the color of the discharges. At the confluence with the Connecticut in September, 1971, there were large floating masses of sludges.

The available information shows a B. O. D. discharge from upstream pollution sources of about 10,000 lbs./day and a C. O. D. discharge of 45,000 lbs./day.

Many of these discharges from industrial plants contain phenols, oil, grease, titanium, chromium, aluminum, and sodium.

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This river is a substantial contributor to the water quality at Northfield, with the average percentage of ten years of records indicating that over 8.00% of the flow to be diverted to Quabbin will be Ashuelot River water.

2) Vermont

(1) Vernon
Vermont Yankee Nuclear Corp., thermal wastes

(2) Brattleboro - Population 8,000
Primary treatment only, combination sanitary - storm sewer

(3) Concel, Inc.
Paper Product Wastes

(4) Boise Cascade Corp.
Paper Product Wastes

(5) Bellows Falls - Population 3,800
Primary treatment only, sanitary - storm sewer

(6) Mt. Paper Products Corp.
Paper Product Wastes

(7) Barrows Coal Company, Inc., Brattleboro
Distributors of Gulf oil and gasoline. All tanks above ground 60,000 gallons of gasoline storage plus 8 fuel oil tank Plants located on the shore of the Connecticut River

(8) American Optical Company
Dye Wastes

The sources of pollution to the Connecticut River in Vermont are limited to the reach from the Vermont line to Bellows Falls. This covers a distance of some 20 miles from the Northfield intake. In this distance are two power dams; one at Bellows Falls, one at Vernon and part of the Turners Falls Pool, which extends to the base of the Vernon Dam.

It is questionable whether all sources of pollution are known, especially old drains connected to the Connecticut River or to adjacent feeder streams.

In September 1971, a fish kill was reported on the Whetstone Brook and in the Connecticut River 1/2 mile south of the Whetstone confluence. Present information indicates the source to be a lumber mill using a chemical solution -- Sodium tetrachloro phenate used in the prevention of fungus growths on wood.

The chemicals from industrial discharges to the municipal sewerage system are not known. The municipal waste systems for Brattleboro and Bellows Falls are combined systems with only primary treatment. The spring ground water infiltration, plus the surface run-off results in a large volume of wastes being by-passed to the Connecticut River at the time of diversion of the Connecticut River to Quabbin Reservoir.

3) Dairy Farming: Massachusetts, New Hampshire and Vermont

A lesser source of pollution during the spring diversion is run-off from agricultural lands and farms. The major dairy farm activity occurs along the eastern side of the Connecticut River from Pine Meadow Brook north to the confluence with the Ashuelot River.

The main agricultural crop is corn -- alfalfa rotation. The dairy herds number 50 or higher per farm.

The farming activity along the west side of the Connecticut River is limited to small farms with dairy herds less than 50. The land adjacent to the Connecticut River is used mainly for cattle grazing.

Dairy farms and their lands adjacent to the river will contribute to the total pollution load during spring run-off. The main pollution would come from cattle manure and fertilizers.

Ammonia and various stages of nitrofication compounds would leach to the river, whereas phosphates would normally reach the river from surface run-off. It is a farming practice to spread commercial fertilizer and manures on the land surface in the late fall, and in early spring before the ground thaws.

Rapid run-off om early spring from rapid snow melt or intense precipitation of rain carries large amounts of organics and inorganics to the river.

There are these numerous sources of pollution along the Connecticut River. Even with high dilution they represent a stress load on Quabbin Reservoir. Perhaps we consider Quabbin as a treatment facility, yet the overall analysis suggests that it does little except to reflect the incoming water quality as it remains in state of normal equilibrium. Perhaps "normal" is best described as that state where there is a biological and chemical balance. The presence of high oxygen demand of water which would cause a depletion of oxygen and loss of species of biota that is natural or normal for that area or body is not a normal condition. Therefore, it is necessary to limit the stress load by control of the above-mentioned sources of stress and by the management of the environment upstream of Northfield to a limit that would reasonably safeguard the water quality at Northfield.

E. Connecticut River Sampling Procedures to Date

1) River Sampling Location

The sampling of the waters of the Connecticut River has been done in an unscientific and haphazard manner. Samples, in general, are grab samples or samples collected from one point. That point may or may not represent the true analysis of the total Q of the river at that particular time. Sampling locations have been picked for convenience, not based on river profiles or flow patterns.

Samples are located mainly at the surface or a short distance below. Sampling procedures conducted by Webster-Martin, Inc. for Vermont-Yankee Nuclear Corp. studies have made a strong bid to locate sampling points and install continuous monitor stations that will attempt to collect a representative water sample.

There is a great need for research in sampling collection locations on large rivers, with flows containing municipal and industrial wastes.

2) Monitor Equipment

Much of the monitor equipment to date requires too much maintenance and is too easily subject to failure. Collection equipment should be capable, not only of continuous draft from the river, but also to be capable of "back-washing" to clear suction lines.

There is a need for more automatic continuous monitoring of parameters to cover a range of chemicals that have an accumulative effect as these substances move up the food chain.

The pumping equipment should be so designed that samples can be taken from more than one depth at the same time.

Each station should be large enough to accommodate an atomic absorption unit and wet-chemistry analysis lab.

3) Study of Analysis from Various Laboratories

The analysis of the Connecticut River water from several agencies shows a wide range of results.

There is a general agreement on color, pH, Dissolved Oxygen, and Hardness, but there are wide differences of several magnitudes in such parameters as ammonia, nitrates, phosphates, iron, COD, turbidity and specific conductance. In some cases, it appears that laboratory procedures are the cause and other cases, it appears to be caused by the continuous change in the water quality from upstream power dam regulations and the periodic discharges from industrial sources.

Until the upstream sources of pollution are eliminated by adequate treatment facilities, there will always be a difference in results on some parameters.

A continuous "trend" in analytical results occurs under natural conditions in areas free from pollution. Quabbin feeder streams are a good example of consistency of chemical quality. There is a real need for standardization of all laboratories -- Federal, State, local and private. Without standardization and inspection and analytical control, the results of analysis and conclusions drawn from this analysis may well be erroneous and may effect judgment of the decision making authority.

6. Discussion

The diversion of water from Northfield Mountain is limited to a period of the year when the flows in the Connecticut River are 17,000 cfs or above at Montague City gaging station. The MDC may divert for that day 375 million gallons or a portion of that amount as determined by the time of the day the flow exceeded 17,000 cfs. For example, at 12:00 noon the MDC would be entitled to divert (375×10^6 gallons) (12/24) for that day.

The investigation of this study has covered an upstream study area from the proposed Northfield Intake on the Connecticut River north to Bellows Falls and east to Keene, New Hampshire.

The chemical quality of the Connecticut River has been reviewed as far back as 1961. The review has covered analysis done by the United States Public Health Service, Federal Water Quality Administration, Massachusetts Department of Public Health, Metropolitan District Commission (Boston), Environmental Protection Agency, New England Research, Inc., and the four year Webster-Martin Engineering Company Studies, conducted for the Vermont Yankee Nuclear Power Corporation, Vernon, Vermont.

The water quality data of Quabbin Reservoir and its feeder streams were reviewed in reports from the Metropolitan District Commission from 1946 to the present. Temperature data was studied from a University of Massachusetts research project and from Metropolitan District Commission records. Additional chemical data was supplied by New England Research, Inc., the Environmental Protection Agency, and the U. S. Army, Corps of Engineers, Barre Falls Laboratory.

Wildlife population information, especially white-tailed deer, was furnished by the University of Massachusetts, Department of Forestry and Wildlife Management.

Reports of diversion flows from Ware River were furnished by Metropolitan District Commission Shaft 8 Headquarters at Barre, Massachusetts.

The general quality of Connecticut River water at the time of diversion is of higher quality than occurs at low flows; however, there are many variables that influence that quality. These are: the upstream sources of municipal and industrial pollution; the regulation of storage and power generation of the some 10 upstream power dams; the major polluted Ashuelot River. The run-off from the Ashuelot occurs at an earlier time than the northern watershed regions of the Connecticut. This earlier run-off contributes at times 8 - 14% of the total river flow at times when water could be diverted to Northfield Mountain and then to Quabbin Reservoir.

The turbidities in the Connecticut River vary with climatic conditions of the season. Turbidities have ranged from 2 to over 100 JCU; while iron has varied .10 - 3.5 mg/l. With industrial waste discharges, the COD has ranged from 18 - 190 mg/l.

The river is well "seeded" with algae. The nutrient load is sufficient to provide production of algae and aquatic plants in a produceable body of water (eutrophic conditions).

There will be the problem of fish and fish eggs from such species as carp and suckers. These are not of public health importance. They have a possible effect of causing increase in turbidity. Such species as carp may cause losses of Salmonidae eggs by depredation or the covering of spawning grounds with silt and other fines. The potential for fish introduction from Connecticut to Quabbin appears to require serious consideration, but is not a part of this appendix.

The temperature differentials between Quabbin Reservoir and the Connecticut River are substantial in late April and May. January through March, the temperature of the Connecticut and Quabbin is about the same. There probably will be an increase in the average daily temperature at Northfield when the nuclear power plant at Vernon, Vermont is in full operation, but without the complete data on temperature, available estimates of that rise cannot be predicted.

The storage of Connecticut River water in Northfield Mountain will probably cause an increase in water temperature. The total rise from all sources may be 1° - 2° F when delivered at Quabbin. Should Northfield Reservoir stratify, then the drawdown to elevation 934 would cause water to be drawn from any epilimnion layer present. A minimum Pond elevation of 962 would probably draft water from any thermocline formed.

As the operation at Northfield Pumped Storage Project reaches full generating capacity, there is far less chance for stratification in the Upper Reservoir.

The degree rise from the Vernon discharge of 780 cfs in March, April and May, will be a maximum of 5° F with an average of 4° F in May. The downstream base flow and possible lower temperatures from the Ashuelot and other streams should limit a rise to 1° - 2° at Northfield. However, should the rise in temperature of 5° F reach Quabbin, it would, in some years, result in premature stratification of the Reservoir. Thus, the Connecticut River water were laying in about the first 20 feet of depth; and with strong winds from the north, the Connecticut water could theoretically reach Shaft 12 in two days according to Alden Hydraulic Lab mathematical studies.

Assuming the elevation of Quabbin to be 500.00 at the time of diversion, the top of the epilimnion at 500 and the bottom at elevation 480, then the present stop-logs at 481.75 to 456.25 would have to be lowered to provide an intake drawing depth into the hypolimnion zone.

The quality of the Connecticut River water during diversion is subject to many factors as previously mentioned. These are the continuous industrial discharges, industrial periodic dumping, municipal combined sewers, fluctuation of the power pools, river velocities that loosen the organic sludges deposited during low flows (such as in the Ashuelot River), run-off from agricultural lands, flooding of cattle pens during the rise of the river, the quality of water in the Northfield Mountain Reservoir (Upper Reservoir) previous to diversions to Quabbin, and the elevation or volume of the upper reservoir.

The storage of thousands of gallons of oil and gasoline a few miles upstream from Northfield remains a hazard. A ruptured oil or gasoline tank during diversion or before diversion could cause great harm should the water be pumped to the Upper Reservoir and even greater harm should it be released to Quabbin Reservoir. It is not an excuse or reason to wave a red flag. It is, however, a warning that Quabbin Reservoir will be used as the "Treatment Plant" for Connecticut River water. Like any treatment plant, there is a load limit both in volume and demand.

The Quabbin Reservoir has never had large demands placed on it. The Ware River and Quabbin direct feeder streams are free of high oxygen demanding materials, industrial pollution or high turbidities. With the exception of color, there is no indication that Quabbin has substantially improved the quality of the incoming water. There is little to improve in the Quabbin feeder streams.

The Quabbin watershed is a highly protected area, free of man-made pollutants. The Ware River watershed is also highly protected by a strict watershed management program on the 96 square miles above the Shaft 8 intake diversion to Quabbin. The Ware River watershed comprises parts of the towns of Barre, Oakham, Rutland, Hubbardston, Westminster, Templeton, Phillipston. These towns, their industries and wastes must conform to the MDC rules and regulations.

Therefore, the streams that feed Quabbin are low in oxygen demand, low in coliforms and trace metals, high in color in the watershed area east of Quabbin Reservoir, low in pH and alkalinity and low in turbidity.

The storage time of diverted Ware River water is less today than 10 years ago. For example, on October 1, 1961, the storage volume in Quabbin was about 399,970 million gallons (399.97×10^9), whereas on January 1, 1971, the reservoir capacity was about 209,000 million gallons (209.0×10^9).

Thus, the flow through Wachusett Reservoir of colder Quabbin water at this volume and elevation provides less retention time. The retention time at Wachusett will be reduced as the draft increases to Boston. By 1990, it is estimated to 440 mgd with a peak draft of 650 mgd.

Presently, there are five other intake works in Wachusett -- Clinton, Fitchburg, Leominster, Worcester and West Boylston. The city of Worcester presently has intake works installed in Shaft 3, Holden, in the Quabbin to Wachusett Aqueduct. There are considerations for the town of Holden to enter Shaft 2, or South Bay, Wachusett and the town of Sterling to enter Wachusett Reservoir. Therefore, it is essential that the water leaving Quabbin is of at least minimum Environmental Protection Agency water quality standards.

The Connecticut River discharge into Quabbin must provide for maximum dilution. This is absolutely necessary. The more flexibility built into this discharge of Connecticut water into Quabbin, the more dilution and less danger of short-circuiting large volumes of water.

The proposed diversion of Connecticut River water into Quabbin is expected in 1976 - 1977. It is expected and essential that the Environmental Protection Agency implementation schedule calls for final approved sewage disposal plans by December 1972 on these upstream sources of pollution. The construction completion date is scheduled for December 1976.

The present quality of the Connecticut River is Class C. Quabbin Reservoir cannot tolerate Class C water over any extended period of time. It is unwise to divert such water, only in a very carefully controlled manner.

The control and treatment of radioactive waste discharges from the Vermont Yankee Nuclear Power Plant at Vernon, Vermont, is not expected to cause any harmful effects in Quabbin Reservoir or to the public health. Monitoring of the Connecticut water below Vernon Dam and an alarm system to Northfield Pumped Storage Facilities is necessary.

The effects of a 5°F rise in the river temperature in April and May may result in stratification at an earlier date in Quabbin. This may also result in a change of elevation of the Shaft 12 stop-logs -- thus requiring the use of the lower bays only.

The spreading of the Connecticut water over the surface could result in a high production of algae and an increase in the COD and BOD loading into the hypolimnion. It could also increase the turbidity substantially at Shaft 12, depending on particle size and its settling rate.

There must be a monitor installation at the Upper Reservoir. This should be installed before the filling of the Upper Reservoir to provide for drawing water from various depths in the pool. A detailed sampling and analysis program should continue from 1972. The monitor should be part of the water quality surveillance program.

Northfield Pumped Storage Power generation will begin by spring of 1972. At least 3 - 4 years of analysis should be done before the Quabbin diversion. This study should cover physical, chemical, radioactivity parameters as required by Environmental Protection Agency for water supply approval.

The Connecticut River has inconsistent quality. Turbidity, coliforms, metals, COD, iron, mercury and occasionally relatively high chromium and cyanide vary over a wide range.

There remains a wide gap in the over-all water quality analysis data to date. There is the problem of analytical methods and practices. The quality data involves many laboratories and individuals. There are many sampling stations covering roughly ten miles of the river. What is a representative sample of the river? The monitor and sampling program located in the Upper Reservoir at Northfield Mountain should be the only true quality reading.

The upstream sources of pollution, especially the paper mills, add large amounts of COD and BOD to the River. The low BOD_5 does not appear to be valid. The ultimate or at least BOD_{20} is required on water discharged to a receiving Reservoir which demonstrates thermal barriers. The presence of ammonia and its oxidation is not exerted in a normal 5 day BOD. The low reading of 1.0 - 1.9 BOD does not appear to indicate the true stored biological demand of the Connecticut River. A clearer indication of the true demand could be calculated if the K rate factor was known.

The introduction of the high oxygen demand water to be stratified in Quabbin in the hypolimnion zone may in time create problems of iron, manganese and sulfide releases from the bottom ooze under zero oxygen conditions.

The Connecticut River, at times, is very high in iron -- as high as 3.5 mg/l and also relatively high in manganese of .20 mg/l. The concentration of sulfates has been as high as 21 mg/l.

The introduction of this water in one area (Middle Branch) of the reservoir may result in high concentration and deposits of Ferric Hydroxide, Manganese Hydroxide, and sulfates. If a significant oxygen depletion were to occur, then water quality problems such as increased iron, manganese and turbidities can be expected. Complete dilution of the Connecticut River water in Quabbin is essential for water quality control. The reduction in the oxygen demanding pollutants from pollution sources upstream of the diversion point must be started. The presence of high nitrogens, phosphates and other nutrients would only stimulate productivity in the Reservoir.

The beginning diversion of Connecticut River waters to Quabbin may occur when the level of Quabbin Reservoir is at Elevation 500.00 and possibly much lower -- perhaps 490.00. At these elevations, the available water for dilution is about 55% of that at Elevation 525. For example, in October 1971, the level of Wachusett was at 375.30 or down some 20 feet from full pond. Assuming a normal low Wachusett elevation of 385.00, instead of the present 375.00 assumed to be by November 1, 1971, the amount of added draft needed from Quabbin to bring the elevation up to 385.00 would be approximately 17×10^9 gallons. Based on the present elevation of Quabbin of 502.90, the added draft of 17.0×10^9 would reduce the elevation of Quabbin to about 500.00.

The introduction of all diverted Connecticut River to the Middle Branch of Quabbin at a Pond Elevation of 500.00 would theoretically reduce dilution to approximately 1-1/2 to 1.

There has been consideration given to the chlorination of the Connecticut River water before entrance to Quabbin. There are two problems associated with this proposal which appear to preclude such a scheme:

(1) The amount of ammonia present in the river water.

(2) The turbidities which range from 2 - 100 JTU.

A third problem for truly effective chlorination of polluted water is the low pH. pH would have to be raised to 7.2 - 7.4 for effective chlorination. This, of course, involves treatment apparatus and a structure. The pH in March averages in the low air range with somewhat higher values in April and May.

The water quality of Quabbin generally reflects the quality of the feeder streams. Natural subsidence has reduced color over 500% and reduced coliforms to near zero.

Turbidity shows a small change from the feeder streams; however, analysis data has not determined what the turbidity was made up of in each case.

The public health hazards associated with the proposed diversion are few, provided the sources of pollution in the Connecticut and Ashuelot Rivers are corrected before diversion and that the distribution of the water in Quabbin be planned such to provide for maximum dilution.

Maximum dilution will help reduce the nutrients below the minimum necessary for growth (law of the minimum) of algae and other plankton. Also, other chemicals will be diluted to acceptable levels for minimum standards requirements.

Short-circuiting of Connecticut River water to Shaft 12 is a real possibility under certain conditions, such as temperature differentials, wind direction, pond elevation and discharge rates. Some control is possible by the regulation of the stop-logs at Shaft 12, based on the analysis data from the Reservoir sampling stations.

There are many protective methods that should be employed to maintain as near as possible the Class A quality of water that now exists in Quabbin Reservoir. It is also essential if Quabbin is to remain in a reasonably steady state condition. It is necessary to improve the quality of the Connecticut River water and to provide for discharge facilities at Quabbin to minimize any adverse effects from low quality water concentrated in one area.

7. Conclusions

Massachusetts legislature has provided the legal means for the Metropolitan District Commission to take water from the Connecticut River when the flows are 17,000 cfs or above, as measured at Montague City. The proposed rate of diversion will be 375 million gallons per day. The river provides flows of 17,000 cfs or above over an average of 70 days per year, usually occurring in March, April, May and June.

The water quality of the Connecticut River at Northfield is Class C at the present time, and is expected to be Class B by the date of planned diversion in 1976, according to Environmental Protection Agency Implementation Schedule.

Water quality studies on the Quabbin feeder streams and Quabbin Reservoir determine that basically the reservoir water reflects the quality of these feeder streams, with the exception of color. Color is reduced by storage from high of 75 - 84 units to 5 - 6 units.

There is some evidence that suggests the oxygen balance at the end of the stratification period in October or early November is decreasing year after year. This, in part, is probably due to the lowering of the reservoir elevation and the corresponding loss in hypolimnion area and the increase in 0_2 demand at the ooze boundary.

The introduction of Connecticut River water into Quabbin is proposed for the Rattlesnake Hill area of the Middle Branch. This water presently has a high COD with a range from 21.0 mg/l to 33.6 mg/l in 1971. The BOD values are based on five days and generally range from 1.9 - 3.0 mg/l, but have, on occasion, reached 17.8 mg/l.

The introduction of Connecticut River water into Quabbin Reservoir must be based on maximum dilution with Reservoir water. This will probably be most critical when the pond is at Elevation of 500.00 or less, when the temperature of the river water and pond water are not the same, and when the wind direction is such to force incoming river water down the pond toward Shaft 12.

One method for obtaining such maximum dilution is to distribute incoming Connecticut River water in at least two locations. This can be done with a dual inlet -- one outlet discharging into the Middle Branch and the second outlet discharging into the West Branch.

Eutrophication in the Middle Branch will occur much sooner than the West Branch. The reduction in the nutrient load and oxygen demanding loads in the Connecticut River water will delay eutrophication. Pollution

abatement schedules and a watershed management policy are essential for water quality maintenance at Quabbin and reduction of the "stress" loads.

Flood skimming of river water, especially polluted water, has its problems of quality in the receiving streams or reservoir. Water treatment installation is uneconomical unless direct water use or storage is possible. The problem against treatment of Connecticut water is the treatment plant costs. Quabbin is not the terminal reservoir on the MDC system. Wachusett is the terminal reservoir. This open-reservoir and its watershed are now subjected to domestic and industrial encroachment. In time, a treatment plant may be required at Wachusett Reservoir. Therefore, good quality is needed at Quabbin to maintain water quality at Wachusett and to reduce eutrophication.

The feeder streams and the Ware River discharge to the Middle and East Branches. These streams have higher color, more turbidity and more iron and possibly higher BOD than the feeder streams of the West Branch. Based on dilution and retention time, the Middle Branch is less conducive to addition of large volumes (20 - 30 billion gallons) of high nutrient, high iron and high COD water.

Regulation of the Shaft 12 stop-logs for water quality control may be necessary until the elevation of Quabbin reaches an elevation of about 520.

The introduction of so-called trash-fish into Quabbin is a real threat. Chlorination of the Connecticut River water would seem impractical and unreliable because of possibly low pH and high turbidity. It may be necessary to think seriously of sand filtration before entering Quabbin.

In conclusion, the system's approach to supplying Quabbin with Connecticut River water is the discharge of water into the reservoir of the highest quality possible. The review of the chemical and biological analysis of Quabbin and its feeder streams indicates that chemical quality changes little from the feeder streams. Perhaps, this is a steady-state condition for Quabbin. Quabbin Reservoir must be protected against high nutrient and high oxygen demand waters. Where these waters, by necessity, enter Quabbin, they must be so mixed and diluted to reduce biological activity and prevent the loss of oxygen in the hypolimnion layer. An oxygen loss through this layer will not only cause a water quality problem at the Chicopee intake, but also at Wachusett.

8. Recommendations

The following recommendations are provided as the necessary procedures to be taken to improve the Connecticut River water quality, attempt to maintain Quabbin water quality, and to provide analysis surveillance to regulate the diversion discharge.

It is proposed that:

(1) A program of watershed management be initiated beginning at Northfield and concluding 20 miles upstream for the purpose of providing and maintaining Class B water at the Northfield Pumped Storage Project Intake Works on the Connecticut River.

(2) The control of farming practices, including erosion control, under the ongoing program of the U. S. Department of Agriculture, Soil Conservation Service, be continued and coordinated with the objectives of this water supply project.

(3) A program for the control of erosion of the Connecticut River banks, including the power pools of Turners Falls, Vernon and Bellows Falls, be initiated.

(4) A permanent monitor and sampling station, with two pump suction lines, for temperature, turbidity, D. O. data and for analysis of other physical, chemical and radiological parameters, be installed at a location in the Connecticut below the Ashuelot River. The location to be determined only after a profile survey and a dye study analysis have been evaluated.

(5) The Vermont Yankee Nuclear Power Company have a relative time schedule established for the discharge of decayed radioactive wastes to the River.

(6) The Northeast Utilities Pump Storage facilities have a radio and telephone alert connection with Vermont Yankee in case of an accidental discharge of high radioactive wastes or failures of the Plant at Vernon.

(7) A permanent sampling station be installed, with wet-chemistry and atomic absorption analysis facilities, and maintained at the Northfield Mountain Reservoir. There should be two drawing depths for the intake suction lines.

(8) No chlorination facilities be installed or maintained at the Upper Reservoir or at the Quabbin Reservoir. Chlorination of upstream discharge from industrial and municipal plants after treatment is advised rather than trying to disinfect high turbid waters.

(9) All construction muck at the discharge point at Quabbin be contained to prevent erosion into Quabbin Reservoir.

(10) For flexibility, dilution, and water quality control purposes, a Y branch be planned for construction to discharge to the West Branch if necessary in the future. Each branch of the Y to be large enough to carry the entire flow from the aqueduct through each leg. At each leg, there shall be a control value to completely shut off the flow or release a portion or all of the flow to the Middle or West Branch. During initial construction at Rattlesnake Hill, the extension stub of the Y to the West Branch should be constructed as far as practicable.

(11) Permanent sampling stations shall be established in Quabbin Reservoir on the Middle Branch to monitor incoming diverted Connecticut River water. This should be an intensive system planned in conjunction with MDC and public health officials.

(12) Thermal photos shall be taken from time to time during the diversion season on the Connecticut River from the Vermont Yankee Nuclear Plant to Turners Falls Dam. If possible, thermal photos should be taken during the spring and fall in 1973 - 1975, or at times when diversion flows are present.

(13) Thermal photos shall be made on the Quabbin beginning April 15 of the year of diversion, during the first year diversion from the Connecticut River.

(14) Any deterioration of any other parameter at Shaft 12 requires consideration for completion of the West Branch Y leg. The decision whether this addition is necessary will be by the MDC and Public Health officials.

(15) The MDC should give serious consideration to the construction and operation of a direct filtration plant without flocculation and settling basin at Wachusett Reservoir. All other communities drafting water from Wachusett should seriously consider the same treatment or connect to the treatment plant.

(16) A separate engineering feasibility study be considered for the relocation of Shaft 12, four miles to the west with a new location or alternate location off the east shore of the West Branch.

APPENDIX H

OPEN PLANNING PROGRAM

This appendix details the "open planning" process utilized to achieve direct participation and coordination of all interested parties. Public meetings, progress meetings, and informational meetings were the main public involvement effort along with a Citizens Participation Board. The following appendix summarizes those meetings, giving a digest of major presentations and the questions and answers given. Also, major public input to the study is detailed.

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APPENDIX H

OPEN PLANNING PROGRAM

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APPENDIX H

OPEN PLANNING PROGRAM

1. General

The study provided for direct participation and coordination by Federal, State, regional and local agencies as well as conservation and citizen groups. This so-called open planning process was achieved through a series of public meetings, progress meetings and informal informational meetings with all concerned. The following sections summarize those meetings and detail the public involvement effects on the study. Complete transcripts of the public meetings are available for review, but digests are included here.

2. Information-Gathering Public Meetings

A. General

Seven public meetings were held at the beginning of the study in New England to explain the background of the study and ask for any information or comments on the conduct of the study. Digests of those seven meetings, held in May and June 1967 at Waltham and Springfield, Massachusetts; Portland, Maine; Concord, New Hampshire; Montpelier, Vermont; Bloomfield, Connecticut; and Providence, Rhode Island, follow:

B. Digest of the 10 May 1967 Public Meeting of the NEWS Study at Waltham, Massachusetts

1) General F. P. Koisch, Division Engineer, North Atlantic Division, presided at this public meeting attended by approximately 80 people.

2) The following is a digest of the presentations made by the major speakers:

a) General F. P. Koisch, Division Engineer, North Atlantic Division, explained the purpose of the public meeting and the objective of the regional water supply study. The Northeastern United States Water Supply Study was authorized in the Omnibus Act enacted in October 1965. The authorization is included in Title I of Public Law 89-298. He noted that while the North Atlantic Division has been assigned

the responsibility for preparation of the 12-State regional NEWS Study, the area within New England would be under the control of the Division Engineer, New England Division. He spoke broadly of the natural supply capabilities of the region and indicated the anticipated population and industrial development projections. In light of the population growth and the continuing industrial development, he stated that it is evident that we face a serious problem in the conservation and management of our water supply sources; and therefore, must formulate a sound program to avoid economic stagnation of what is now the most mature area of our nation.

b) Mr. Albert H. Zabriskie, Director, Massachusetts Department of Natural Resources. Mr. Zabriskie, on behalf of his Commissioner, offered the full cooperation of the State of Massachusetts.

c) Mr. Jack A. Gedden, Staff Assistant, White Mountain National Forest, Laconia, New Hampshire, presented a statement in behalf of Mr. G. S. Wheeler, Forest Supervisor, White Mountain National Forest, Forest Service, U. S. Department of Agriculture. The statement described the White Mountain National Forest and the authority and responsibility of the U. S. Forest Service in administering forest lands. He noted the interest of the Forest Service in obtaining optimum resource management of forest lands with emphasis on water resources protection. The statement concluded with a wish for continued cooperation with all Federal, State, and local agencies concerned with water supply and water pollution to assure that the Forest Service multiple-use activities are coordinated with the requirements of such agencies.

d) Mr. Martin Cosgrove, Deputy Chief Engineer, Construction Division, Metropolitan District Commission. Mr. Cosgrove expressed the vital interest of the Commission in planning for long range water supply of those communities that now and will in the future serve. He traced the regional water supply planning accomplishments of the Boston area back to 1895 when a report of an exhaustive study of possible sources of water supply from Cape Cod to the south, to the Sebago Lake on the north, and west to the Berkshires. He concluded that the expansion of Metropolitan Boston's water supply must be to the west. As a result, the Nashua River was developed with the construction of Wachusett Reservoir. In 1922, the metropolitan area water supply problems were reviewed by a joint board consisting of the MDC and the Massachusetts Department of Public Health. The conclusions of the previous study were verified and the Ware and Swift Rivers were developed by construction of Quabbin and the Quabbin aqueduct, together with the Ware River intake. He noted that the safe yield of the present sources of supply is

330 mgd and the projections indicate that the needs of the system in 1980 will be 380 mgd and in 2040, 520 mgd. Mr. Cosgrove noted that the MDC is investigating the use of excess water from the Millers River and other sources such as an average of 72 mgd from the Connecticut River through the Northfield Mountain pumped storage facilities during a 70 to 80 day period when the flow in the Connecticut River is above 15,000 cfs. He also referred to studies by the MDC on the possible enlargement of Tully Reservoir for water supply up to a total of 85,500 acre-feet. He noted that the MDC is supplying water to 11 cities and towns outside the limits of the District, some of them in the Connecticut River Valley. He also submitted to the hearing officer, reports to the legislature on recent studies which contained factual data that may be of interest to the study.

e) Mayor Edward F. Harrington of New Bedford. Mayor Harrington noted that southeastern Massachusetts contains the largest mass of population in the State, outside of the Boston Metropolitan area. It includes the cities of Taunton, Fall River and New Bedford. He referred to the large uses of water within the three cities by industrial users. He described efforts of southeastern Massachusetts to formulate a district and receive assistance from the Economic Development Administration and to make a determination as to what steps are needed in the long range basis for water resources. A list of reports from 1953 up to the present time was submitted as input to the study. Mayor Harrington recommended that the Corps make an immediate comprehensive engineering study of the entire southeastern Massachusetts area. He felt specifically there should be a study of the unharnessed area of water at Fall Brook. Second, the city of New Bedford has completed a survey which indicates that one of its four reservoirs could increase its annual storage by 1.75 million gallons. Also, by raising the levels of certain other ponds in the Lincoln watershed, the storage facilities of southeastern Massachusetts could be increased by an additional 3 to 4 million gallons. Further, he felt, a study should be made as to the possibility of harnessing the waters of the Taunton River to make it available to the people of southeastern Massachusetts on a long-term, continuing basis. Finally, he felt, that if the study indicates that other sources are not adequate to meet projected needs of the year 2000, then the Corps should consider the possibility of constructing a desalinization plant in southeastern Massachusetts.

f) Mayor Benjamin A. Friedman, Taunton, Massachusetts. Mayor Friedman indorsed the sentiments of the Mayor of New Bedford, stating that his community had similar water supply problems. He noted that the area has adequate water supply and that the problem

is to eliminate pollution from many of the sources, particularly the Taunton River, which has a potential of 80 million gallons per day on a safe yield basis. The three communities, New Bedford, Fall River and Taunton, by 1990, will have a potential demand of 59 million gallons a day and by use of the cleaned-up Taunton River, future needs could be met.

g) Mr. Spaulding E. Owen, Director of Public Works, Rockport, Massachusetts. Mr. Owen noted that his community, with a population of 5,297, is small, but in the summer has a temporary population of 8,000 people. The town of Rockport has a water problem and is interested in all avenues of advice and help in the solutions thereof.

h) Mr. Edward P. Grace, City Councillor, Fall River, Massachusetts. Mr. Grace, as a member of the City Council and as Chairman of the Water Resources Committee, cited the following problems in Fall River:

-- Fall River, with a population of 100,000, serves outside interests such as Tiverton, Rhode Island and Somerset, Massachusetts for a combined service of 115,000 people.

-- The city has two sources from which it could obtain additional water supply, and they are the Copicut area with a yield of 6 million gallons per day; and Rattlesnake Brook with a yield of 3 million gallons per day. He indicated that it would helpful if the Corps of Engineers could make a survey of those two particular areas.

i) Mr. Fred K. Hanach, Superintendent of the Department of Public Works, town of Dartmouth, Massachusetts. Mr. Hanach noted that the two watersheds referred to by the previous speaker, are located in the town of Dartmouth, but through a legislative act, the city of Fall River has the water rights and the town of Dartmouth does not. He indicated that a study should be undertaken of the legislative plight of smaller communities so that equity can be achieved on a regional basis for smaller as well as large communities.

j) Mr. Kenneth F. Knowlton, Chairman, Ipswich River Watershed District Commission, Beverly, Massachusetts. Mr. Knowlton noted that the Ipswich River District was a newly formed district as a result of four regional studies by the Massachusetts Water Resources Commission. There are four water resource reports on the Ipswich River, done by the U. S. Geological Survey. The Ipswich River Watershed District contains 23 cities and towns with a current population of

400,000 and an anticipated year 2000 population of 500,000. It is expected that by the year 2000, the district will have exceeded the water resources of the Ipswich River. Because of the need for the district to make efficient use of its resources, it is extremely interested in the long range water supply study being conducted by the Corps of Engineers.

k) Mr. Charles J. Strumski, President, Norfolk County League of Sportsmen's Clubs. Mr. Strumski noted that he represented the Norfolk County League of Sportsmen's Clubs and the Massachusetts Federation of Sportsmen's Clubs for Massachusetts Wildlife Federation. He expressed the interest of sportsmen in fish and wildlife and recreation and hoped that the study would consider the smaller watersheds and impounding basins as a means of supplying the brooks and increasing groundwater supply.

3) At this point, General Koisch noted that he had reached the end of prepared statements and asked for statements from the audience or questions.

a) Mr. Frederick L. Tripp, Water Commissioner, City of Taunton. Mr. Tripp noted, as he had only recently retired as Deputy Chief Engineer, Department of Public Works, he had a fairly comprehensive view of the water needs of the State. He indorsed the comments of the Mayors of New Bedford and Taunton and Fall River, expressing needs for study of Bristol County in southeastern Massachusetts and stated that he was in favor of any studies that would increase and aid the continued supply of water for future needs.

b) Mr. Earle Gaudette, City Councillor, Fall River, Massachusetts. Mr. Gaudette also indorsed the statements made by the Mayors of New Bedford and Taunton and for himself would like to see the development of the Taunton River to take care of surrounding communities.

c) Mr. John H. O'Neil, Councillor, City of Fall River. Mr. O'Neil noted that he was happy that the Corps of Engineers had undertaken the study, and felt the need for regional cooperation, regional financing of several programs, particularly within Bristol County.

d) Mr. Frank Dickson, Executive Vice President, New Bedford Area Chamber of Commerce. Mr. Dickson supported the statements of previous speakers which indicated the need for broad comprehensive study of the water problems of southeastern Massachusetts.

e) Mr. Alfred C. Anderson, Director of Public Works, Northeastern Area Office, Economic Development Administration, Portland, Maine. Mr. Anderson noted that his office covered the region of New England and New York State and that he was representing Mr. Edward Webber, Director for the Region. Mr. Anderson recognized the critical importance of comprehensive planning in the field of economic development and stated that his agency is involved in the expenditure of funds for public works, among which are water projects. Because of his agency's involvement in public works, he expressed his desire to engage in coordinating comprehensive planning in water resources and noted that his agency would coordinate to supplement the planning actions taken by the Corps of Engineers. He also noted that his agency is working closely with the Department of the Interior, Federal Water Pollution Control Administration in providing funds and plans for construction, as well as planning funds to resolve some of the public works problems, including water supply.

4) At this point, General Koisch read several statements he had been asked to read into the record, as follows:

a) A statement from Hon. Torbett H. McDonald, U. S. Representative, 7th District of Massachusetts, which said he was extremely interested in programs of conservation of natural resources and would follow the results of the study closely as they developed.

b) Governor John Volpe, Massachusetts, urged his wholehearted support of the program, requesting that the study maintain coordination with Malcolm E. Graf, Massachusetts Division of Water Resources, as well as Mr. John C. Collins, Director of the Sanitary Division of the Department of Public Health and MDC Commissioner Howard Whitmore, Jr.

c) From the Department of the Interior, Federal Water Control, a statement noting that agency's authority and interest in water pollution, water quality control, and the programs which it has under way at the present time. Because of the agency's authority interested programs, it would like to maintain close coordination during the study.

d) A letter from Federal Highway Administration, Department of Transportation indicating that that office would cooperate in any way possible by supplying the Corps with data regarding the effects of highways on any plan developed by the study.

e) A letter from Mr. Robert A. Hancock, Town Manager, Town of Provincetown, Massachusetts, noting that consultants for the town had been studying two sites for water supply, located within the

national seashore. The town is negotiating with the national seashore for long term rights to develop these sites on the basis that it is in the long term best interests of our region; namely, Provincetown, the town of Truro and the national seashore. He hoped that the study would approve the town's approach to the solution of its long term water supply needs.

f) A letter from Putnam, Thomas and Kimball, Attorneys at Law, 11 Beacon Street, Boston, Massachusetts, stating or rather directing attention to a situation that exists in Norfolk and surrounding towns where certain storage facilities are inadequate and where water shortages are becoming common occurrences during the summer months. A USGS study has just been completed of groundwater Norfolk area. Studies have been completed by a consultant, making recommendations for improved water supply in the area and officials of the town of Norfolk are recommending a regional water district as the best way to marshal financial and professional resources of the area to cope with what is certain to be a long range problem. The letter urged the Corps of Engineers to give consideration to that area of Massachusetts and to assist in locating financing and building reservoirs both of the magnitude of Quabbin and also of a smaller size.

g) A letter from Mr. Philip H. Crane, President, Somerville Community Council. The letter urged that the class E rating for the Mystic River Basin be upped to Class B, as the population of Somerville is condensed into four square miles and the 86,000 people located therein are sorely pressed to develop recreational facilities.

5) Questions were then answered.

a) In response to a question from Mayor Harrington, General Koisch replied that the study is planned for a 5-year period with an approximate cost of $6 million, just for the study. The study is just in its early stages and the first step will be to elicit those areas where the water supply problems are urgent. Within 18 months, the study should determine which direction it is going within each of the New England States.

b) In response to a question by Mr. Edward P. Grace, who requested the name of some source from which the city of Fall River might obtain equipment to develop its water resources, General Koisch suggested that the New England Division office in Waltham be contacted.

c) Mr. Michael Collins asked if hydrology reports by consultants would be sent into the various cities and towns. General Koisch replied that the U. S. Geological Survey has agreed to make available to us all of the hydrology information.

6) At the close of the meeting, General Koisch received a telegram stating that the Needham Chamber of Commerce was unable to be represented at the meeting, but wished to go on record as supporting the study.

7) The meeting adjourned at 3:30 p.m.

C. Digest of the NEWS Public Meeting of 9 May 1967 at Springfield, Massachusetts

1) Presiding at the meeting was General F. P. Koisch, Division Engineer, North Atlantic Division. Approximately 50 people attended the meeting at Springfield.

2) The following is a digest of the major presentations:

a) General F. P. Koisch, Division Engineer, North Atlantic Division, explained the purpose of the public meeting and the objective of the regional water supply study. The Northeastern United States Water Supply Study was authorized in the Omnibus Act enacted in October 1965. The authorization is included in Title I of Public Law 89-298. He noted that while the North Atlantic Division had been assigned the responsibility for preparation of the 12-State regional NEWS Study, the area within New England would be under the control of the Division Engineer, New England Division. He spoke broadly of the natural supply capabilities of the region and indicated the anticipated population and industrial development projections. In light of the population growth and the continuing industrial development, he stated that it is evident that we face serious problems in the conservation and management of our water supply sources, and therefore, must formulate a sound program to avoid economic stagnation of what is now the most mature area of our nation.

b) Malcolm E. Graf, Director and Chief Engineer, Massachusetts Division of Water Resources, Boston, Massachusetts. Mr. Graf expressed concern for the regional water supply problems and promised full cooperation and coordination by the State.

c) Robert D. Deemer, Water Staff, Green Mountain Naticnal Forest, Forest Service, U. S. Department of Agriculture. Mr. Deemer presented a statement by Paul S. Newcomb, Forest Supervisor, Green Mountain National Forest. The statement described the extent and location of the Green Mountain National Forest and summarized the authorities and responsibilities of the Forest Service in administering National Forests. The primary goal of the Green Mountain National Forest is to provide sustained yields of products and services that will best meet the needs of the American people through multiple-use management of the forest resources -- water, outdoor recreation, wildlife and timber. Watershed objectives are to regulate stream-flow, control floods and erosion and maintain favorable water quality for the maximum benefit. Mr. Deemer extended the cooperation of his agency in the development of plans to meet the long-range water supply needs of the Northeastern United States.

d) The fourth speaker, Mr. A. Donald Caven, Franklin County Planner. Mr. Caven noted that Franklin County consists of 730 square miles and 26 towns, located in the watersheds of the Connecticut, Millers, and Deerfield Rivers. The area is obviously a source of water supply for other more populated areas of the State. The county is eager to cooperate, provided that the water supply districts within the county can meet their own needs. He further feels that the regional approach is an ideal way to handle this type of water supply planning.

e) Mr. John M. Turner, Water Manager, Springfield, Massachusetts. Mr. Turner thanked the Corps of Engineers for its past assistance in constructing Littleville Dam on the Westfield River and providing the City of Springfield with an ideal future source of water supply. He stated that the water supply from Littleville isn't only for the City of Springfield but can also be used for Westfield, Southbridge, Longmeadow, Agawam, Ludlow, parts of Wilbraham. He spoke of the problems that communities such as Springfield have in providing a dependable and available source of water supply. He stated that financial assistance, modern treatment facilities, and larger distribution capabilities must be provided so that all potential unused water in other portions of the State can be made available for the unforeseeable future needs of the lower Connecticut Valley area or any other area. In summary, he noted that although the Connecticut Valley is rich in its water resources, the problem is to collect the unused water and place it where it can be useful.

f) Mr. K. M. Munnich, Planning Director, Lower Pioneer Valley Regional Planning Commission. Mr. Munnich expressed the interest of the Commission in the study and offered its cooperation in any future work by the Corps. The Commission covers the area of two counties, Hamden and Hampshire, and represents 43 towns and cities.

g) Colonel Carroll E. Adams, U. S. Army, retired, Shelburne Falls, Massachusetts. As a resident of the town of Charlemont, Massachusetts, Colonel Adams noted his familiarity with the resources of the Deerfield River and its tributary, the Green River. A study made some 60 years ago identified 8 sites for water power dams and only one of those sites, at Zoar, has not yet been developed. The feasibility of a low-level dam at the Zoar site should be determined. Three existing New England Power dams at Shelburne Falls should be reconsidered for recreational purposes, streamflow regulation, pollution abatement and especially for water supply for urban areas downstream if not needed at Shelburne Falls. There are two main sources of pollution on the Deerfield River. One caused by the Deerfield Glacine Company at Munroe Bridge and the other from the discharge of raw domestic sewage from homes in Charlemont. Generally, he felt that the Deerfield has a tremendous potential for water resource development and it should be exploited to the fullest extent. On the Green River, there is an excellent potential for the river to be used as a stand-by supply for potable for the Greenfield area. Pending its need as a domestic supply, the area could be used for recreational purposes, boating, fishing, camping, etc.

h) Mrs. Edward Jones, Water Resource Co-Chairman, League of Women Voters, Springfield area. The League feels that water supply should be solved on a regional basis. The Lower Pioneer Valley Regional Planning Commission, with 30 member communities, has been doing research on both water supply and sewage disposal and its findings should not be duplicated, but incorporated into State or Federal planning. More geologic mapping should be done. The League supports the bill in the Massachusetts House Legislature to provide funds for geologic mapping. Mrs. Jones also cited the problems that Springfield has had in recent years providing an adequate supply of water and the addition of water supply facilities in the Littleville flood control reservoir as a means of meeting near future needs. Mrs. Jones stated that a regional or Metropolitan District Commission is needed in that portion of the State and its members should be many if not all of the Lower Pioneer Valley Regional Planning Commission.

3) At this point in the meeting, General Koisch referred to communications he had been asked to read into the record of the various meetings. The following are several of those communications:

a) From Governor Volpe, a letter indicating his backing of the study, his interest in it and his offer of cooperation.

b) A letter from the U. S. Department of Transportation, Federal Highway Administration, Public Roads, Region I, indicating its intent to cooperate in any way possible by supplying data regarding the effect of highways on any plan developed by the study.

c) A letter from the U. S. Department of the Interior, Federal Water Pollution Control Commission, Northeast Region, outlining the programs under way by the Administration which may significantly effect the development of regional water supply plans, and indicating a desire to maintain close coordination throughout the study.

d) A paper presented by Mr. Howard C. Smith, President, Westfield River Watershed Association, describing the topography, hydrology, and resources of the Westfield River Valley and offering proposals for consideration in planning water supply to meet basic human needs, as follows: (1) Provide storage of streamflow to meet municipal water supply needs; (2) explore groundwater resources; (3) weigh the cost of taking water directly from the rivers versus impoundments; (4) find the use of high quality municipal water to conventional human needs; (5) establish a direct commission for water supply for the Lower Pioneer Valley communities.

The paper also referred to the needs of industry in the Westfield River for adequate flow for manufacturing processes, as well as for the needs of potential water-related recreation activity. Specifically, the association proposed: (1) one or more multiple-use flood protection dams be built on the main river above the present Knightville Dam; (2) these dams be so designed and operated together with the existing Knightville Dam to store excess flows to meet minimum industrial needs; (3) complete at the earliest possible date, a series of dams for the West Branch of the Westfield River which are being planned at the present time to provide for low flow augmentation, recreation and favorable fish and wildlife environment; (4) allow for multiple, including recreational, use of municipal water supply impoundments in streams tributary to it.

4) General Koisch then asked for comments or questions from the floor and the following responded:

a) Mr. Edmund J. Gleason, Massachusetts State Council of Sportsmen's Clubs, and Hamden County Sportsmen's Club, referred to the possible conversion of pollution water by atomic energy, specifically, the plants at Rowe and the one going up in Haddam. He noted that the region does have groundwater as proven by geodetic surveys and other water surveys throughout the Connecticut River Valley and the New England area. He noted that sportsmen have been more of a conservationist group than any other group that has been formulated in the past 10 years, because they have been working on conservation for the last 60 or 70 years. He referred to the closing of Littleville Dam to recreational activities, noting that similar future closings for water supply will eliminate a significant amount of land available for recreational purposes.

b) Mr. Wiley Hubbard, City Engineer, City of Springfield, asked if the Corps had been asked for a recommendation or any opinion as to the proposal of Northeast Utilities to divert some water from the Connecticut watershed into the Metropolitan Boston area. In response, Mr. Hill, Planning Branch, New England Division, Corps of Engineers, was aware of the Metropolitan District Commission's study, but had not yet rendered any opinion.

5) The meeting was concluded at 2:55 p.m.

D. Digest of Public Meeting, 6 June 1967, at the University of Maine, Portland, Maine

1) General F. P. Koisch, Division Engineer, North Atlantic Division, presided at the public meeting, with approximately 25 people in attendance.

2) A digest of statements made at the meeting follows:

a) General F. P. Koisch, Division Engineer, North Atlantic Division. General Koisch explained the purpose of the public meeting and the objective of the regional water supply study. The Northeastern United States Water Supply Study was authorized in the Omnibus Act, enacted in October 1965. The authorization is included in Title I of Public Law 89-298. He noted that while the North Atlantic Division has been assigned the responsibility for preparation of the 12-State regional NEWS Study, the area within New England would be under the control of the Division Engineer, New England Division. He spoke broadly of the natural supply capabilities of the region and indicated the anticipated population

and industrial development projections. In the light of the population growth and the continuing industrial development, he stated that it is evident that we face a serious problem in the conservation and management of our water supply sources, and therefore, must formulate a sound program to avoid economic stagnation of what is now the most mature area of our nation.

b) Mr. Charles L. Boothby, Executive Secretary, Maine Soil and Water Conservation Committee. Mr. Boothby represented Maine's 16 Soil and Water Conservation Districts and the 10,000 cooperating land-owners. Mr. Boothby recognized the need for better management of our resources to meet the tremendous pressures that can be expected in the future. He noted the balance between food and population and the need to conserve our productive land to raise food. He noted that several factors which are limiting the supply portion of the equation of potable water supply are water quality, number and size of potential new reservoirs, and sedimentation of present reservoirs. He noted that recent projections made during the up-dating of the Conservation needs inventory, indicate that the smaller communities, as well as larger ones, are strongly considering municipal water supplies and accordingly the Conservation Committee urges that the smaller communities also be included in any basin-wide plans.

3) At this point, General Koisch noted that there were no other prepared statements, and therefore, he presented letters and notices which had been received for the record.

a) The Governor of Maine and the Federal Senators and Congressmen had offerred their cooperation to the study.

b) Also, the U. S. Department of the Interior, Federal Water Pollution Control Administration, presented a statement outlining the programs under way by the Administration which may significantly affect the development of regional water supply plans, and indicating a desire to maintain close coordination throughout the study.

4) There being no other communications, presentations, or questions, General Koisch adjourned the meeting.

E. Digest of the 7 June 1967 Public Meeting of the NEWS Study At Concord, New Hampshire

1) General F. P. Koisch, Division Engineer, North Atlantic Division, presided at the public meeting attended by some 30 people.

2) The following is a digest of the presentations made by the major speakers:

a) General Koisch delivered the opening remarks, explaining the purpose of the public meeting and the objective of the regional water supply study as he has done at the other informational public meetings.

b) Mr. Clarence E. Ferry, Assistant Superintendent, Water Department, Manchester, New Hampshire. Mr. Ferry extended the full cooperation of the Manchester Water Works and would gratefully acknowledge any technical or financial assistance from this study.

c) Mr. Donald C. Calderwood, President, Pennichuck Water Works, Nashua, New Hampshire. Mr. Calderwood raised the question about how investor-owned utilities might benefit or participate in this program.

d) Mr. Arthur Faneuf, Superintendent of the Concord Water Works, Concord, New Hampshire. Mr. Faneuf stated the city's financial problem concerning water supply and wondered what assistance the Federal Government might be.

3) Since no one else wished to make a statement, General Koisch read several letters received concerning the study:

a) Mr. G. S. Wheeler, United States Department of Agriculture, Forest Service, White Mountain National Forest, wrote that they being watershed managers want to cooperate and work closely with the Corps in this study.

b) The Commissioners of the North Walpole Village District, North Walpole, New Hampshire, wrote asking what assistance the Corps could be in their water supply problem. It seems that their present wells and springs are inadequate during the summer months.

c) Mr. Lester M. Klashman, Regional Director, Northeast Region, Federal Water Pollution Control Administration, U. S. Department of the Interior, wrote that they are presently engaged in

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several programs which may effect the development of a regional water supply plan and he would like to maintain close coordination with this NEWS Study.

4) The General proceeded to ask if there were any questions from the audience. Since there were no questions, the meeting was adjourned.

F. Digest of the 8 June 1967 Public Meeting of the NEWS Study At Montpelier, Vermont

1) The Public Meeting was presided by General F. P. Koisch, Division Engineer, North Atlantic Division. Approximately 30 people were in attendance.

2) The following is a digest of the presentations made by the major speakers:

a) General F. P. Koisch delivered the opening remarks, explaining the purpose of the public meeting and the objective of the regional water supply study as he did at the other informational public meetings.

b) Mr. Reinhold W. Thieme, Commissioner, Vermont Department of Water Resources. Mr. Thieme felt that in Vermont there is a good supply of water available and the only problem is getting the water to the right place when needed. To this end, the State of Vermont has established a number of programs to aid the individual municipality in planning and developing systems to meet their water supply needs, which he explained in some detail. He ended his statement by hoping that the NEWS Study would provide an assessment of his neighbors' problems and possible solutions so that a coordinated plan could be developed.

c) Mrs. Newton G. Garland, representing the Vermont League of Women Voters, from Burlington, Vermont. Mrs. Garland, on behalf of the League, commended the Corps on this study and urged that the study should give full, comprehensive consideration to the different ways in which water can be used. Equally important, she felt, is that the citizens of the region be involved in policy decisions regarding the direction water resources development will take.

d) Mr. Justin Brande, Chairman, Vermont Natural Resources Council. Mr. Brande stated from the outset that his organization looks upon the prospect of any major withdrawal of water from even the larger lakes or streams of this State with a certain amount of apprehension and misgiving. He felt that the water budget of Vermont is already at a critical balance point. Therefore, it is imperative that we push forward our program of waste treatment and all forms of water salvage. He hoped that we would put out house in order first before investing in extravagant schemes that may cause serious disruptions.

e) Mr. Chauncey Dunton of Salisbury, Vermont, Co-Chairman of the Lake Champlain Committee. Mr. Dunton represented a conservation organization of approximately 1200 members which was formed in 1963 to oppose the construction of a seaway through Lake Champlain. Currently, the organization is encouraging the elimination of pollution of Lake Champlain. He stated that Lake Champlain is a priceless asset to the area, and as such, has no substitute. In conclusion, he requested the Lake Champlain Committee be placed on record as strongly in favor of preserving for the pleasure and use of future generations a clean, beautiful and unspoiled Lake Champlain.

f) Mr. Burton M. Ball of Rutland, Vermont, representing the Vermont Yankee Nuclear Power Corporation. Mr. Ball detailed the nuclear power station to be located on the Connecticut River at Vernon, Vermont. He noted that additional power plants in the future may require additional upstream impoundments. He heartily endorsed the water supply study.

g) Mr. Gerald Irvine, Water Commissioner of Essex Junction, Vermont. Mr. Irvine outlined the formation of the Champlain Water District and what it has done to date. He ended by stating that the greater Burlington area's water requirements will double by 1970 and they would like to keep Lake Champlain as pure and clean as possible.

h) Mr. Warner Shedd, President, Vermont Federation of Sportsmen's Clubs. Mr. Shedd voiced concern that this study might recommend that the waters of Northern New England would be diverted for water supply to the southern metropolitan areas. He felt that instead a massive effort to reduce pollution in our rivers should be instituted. This type of program would: (1) provide a vast supply of potable water for water supply; (2) leave the upper reaches in their natural state for recreation; and (3) open a whole new series of recreational possibilities close to the metropolitan areas.

i) Mr. Robert Diemer, Green Mountain National Forest, Rutland, Vermont. Mr. Diemer stated the function and benefits of the Green Mountain National Forest. He also extended his organization's cooperation in the NEWS Study effort.

3) Since there were no further prepared statements, General Koisch read from several letters received concerning the study.

a) Dr. Joseph Rudmin, Commissioner, INCOCHAMP, wrote that it is necessary the INCOCHAMP be involved in the long-range plan development of Public Law 89-298, involving its application to the waters of Lake Champlain.

b) Mr. Lester M. Klashman, Regional Director, Northeast Region, Federal Water Pollution Control Administration, U. S. Department of the Interior, wrote that they are presently engaged in several programs which may effect the development of a regional water supply plan and would like to maintain close coordination with this NEWS Study.

4) General Koisch then asked if there were any further statements or questions from the floor. Since no questions were forthcoming, the meeting was adjourned.

G. Digest of the 13 June 1967 Public Meeting of the NEWS Study At Bloomfield, Connecticut

1) General F. P. Koisch, Division Engineer, North Atlantic Division, presided at the public meeting attended by some 25 people.

2) The following is a digest of the presentations made by the major speakers:

a) General Koisch delivered the opening remarks, explaining the purpose of the public meeting and the objective of the regional water supply study as he did at the other informational public meetings.

b) Mr. E. P. Williams, President of the Connecticut Water Company, Clinton, Connecticut, and Chairman of the Water Resources Committee of the Connecticut Water Works Association. Mr. Williams requested the opportunity to exchange information and advice with study team in the preparation of regional plans in order to assure harmony with individual communities' planning.

c) Mr. Donald W. Loiselle, Assistant Vice President, Bridgeport Hydraulic Company, Bridgeport, Connecticut. Mr. Loiselle stated that his company which services ten towns in Fairfield County area has developed plans to provide water service for their area through the year 2020. They would, however, appreciate the opportunity of working with the Corps of Engineers cooperatively on any problems in our area.

d) Mr. Joseph A. Navaro, Chief Engineer, New Haven Water Company, New Haven, Connecticut. Mr. Navaro stated that because of their long range planning, no restrictions on water use had to be instituted during the drought and they already own the property and the streams to meet their projected needs for the year 2000.

e) Mr. Richard Woodhull, Chief, Water Supply Section, Connecticut Department of Health. Mr. Woodhull pointed out that the Connecticut State Legislation had recently passed a law authorizing a one and a-half million dollar state-wide study of water-sewage planning which he hoped would be coordinated and integrated into our planning.

f) Mr. Gilbert V. Gustafson, Deputy Manager, Metropolitan District, Hartford, Connecticut. Mr. Gustafson stated that his company was also in the process of developing plans to meet their water needs to the end of the century. They would appreciate the opportunity to discuss possible plans with the Corps.

3) Since no one else wished to make a statement, General Koisch read several letters received concerning the study:

a) Honorable Thomas C. Mayers, Mayor, Stamford, Connecticut, wrote concerning the water supply problems of that city in which serious water restrictions had to be placed on the population in three different years. He hoped that a regional system could be set up to aid his city and that studies of the ground water supplies of the area could be made.

b) Mr. Lester M. Klashman, Regional Director, Northeast Region, Federal Water Pollution Control Administration, U. S. Department of the Interior, wrote that they are presently engaged in several programs which may effect the development of a regional water supply plan and he would like to maintain close coordination with this NEWS Study.

4) The General proceeded to ask if there were any questions from the audience. Since there were no questions, the meeting was adjourned.

H. Digest of the 14 June 1967 Public Meeting of the NEWS Study At Providence, Rhode Island

1) General F. P. Koisch, Division Engineer, North Atlantic Division, presided at this Public Meeting, attended by some 25 people.

2) The following is a digest of the presentations made by the major speakers:

a) General Koisch delivered the opening remarks, explaining the purpose of the public meeting and the objective of the regional water supply study as he did at the other informational public meetings.

b) Mr. Henry Ise, Chief of the Rhode Island Division of Rivers and Harbors. Mr. Ise stated that the Federal Government should enact appropriate legislation that would assure the availability of water supply for all the needs of our citizens. He felt that such development represents a gigantic undertaking which cannot be left to be done on a piecemeal basis by municipalities and small private water companies. The Federal Government should assume the primary responsibility in the field of public water supplies.

c) Mr. Henry F. Munroe, Staff Engineer, Rhode Island Water Resources Coordinating Board. Mr. Munroe, on behalf of the Water Resources Coordinating Board, explained what effect the drought had on Rhode Island and what programs and improvements the state has made in recent years. In their planning, the state realizes a master plan must be developed on a regional basis and definite consideration given to the importation and exportation of water over state boundaries.

d) Mr. John McManus, Water Superintendent for the City of Pawtucket, Rhode Island. Mr. McManus explained how the City of Pawtucket had to institute water restrictions during the drought. Since that time, they have been looking to the State for additional sources of supply. He ended by stating that the City of Pawtucket water system would cooperate in any way possible with the study team.

e) Mr. Phillip J. Holton, Chief Engineer of the Providence, Rhode Island Water Supply Board. Mr. Holton spoke on the adequacy of the Providence supply and the long range program under way by the Board. The Board did not have restricted water use during the drought. In fact, at the lowest point, they had enough water in storage to meet the needs of the system for over a year. Their long range

program involves the Wood River development, a supplementary aqueduct and a large number of distribution system improvements. This work is expected to require a capital expenditure of around 16 million dollars.

3) General Koisch then read a letter from Mr. Lester M. Klashman, Regional Director, Northeast Region, Federal Water Pollution Control Administration, U. S. Department of the Interior, since there were no further statements. Mr. Klashman wrote that they are presently engaged in several programs which may effect the development of a regional water supply plan and he would like to maintain close coordination with this NEWS Study.

4) The General proceeded to ask if there were any questions from the audience. Since there were no questions, the meeting was adjourned.

3. Meeting on the Results of the Feasibility Study

After these meetings, reconnaissance and feasibility reports were prepared and reviewed by Federal, state and local officials. On 7 May 1970, a meeting with those interested officials was held to decide on the next course of action. The following is an excerpt from the summary letter sent to all participants in that meeting:

> Your active participation at the 7 May 1970 meeting in Boston, relative to the NEWS Study was most helpful in delineating some of the immediate actions that might be undertaken, with some degree of confidence in their ultimate value and acceptability. Comments were requested which would aid the NEWS study staff in selecting projects for detailed environmental, engineering, social and economic studies that should be initiated now, so that available manpower and funds may be utilized in the most efficient manner. The following statements represent our interpretation of the consensus reached by the group present at the meeting:
>
> a. The Corps of Engineers should proceed with detailed studies on the development of Tully Reservoir.
>
> b. The Corps of Engineers should consider the Northfield Mountain development as a very viable element in

any regional water supply plan that might be implemented for southeastern New England. Accordingly, the Corps should initiate detailed studies on this project, and these studies should be designed to complement those already under way or planned by the Metropolitan District Commission.

c. The Corps should begin detailed studies on the requirements for improving the water quality of the Merrimack River to the degree necessary to support its use as a water supply source. As part of these studies, the Corps should determine the resource needs of the current and projected population of southeastern New Hampshire as they might relate to development of the Merrimack River.

d. The Corps should conduct a broad environmental impact study of all alternatives proposed thus far for southeastern New England.

e. The Corps should conduct a detailed study specifically directed at determining the effects of upstream diversion on the estuaries of both the Merrimack and Connecticut Rivers. Included in this should be a systems study of the joint operation of both rivers to serve southeastern New England.

f. The Corps should explore the possibilities of advanced site acquisition, beginning in the State of Rhode Island.

Your review of the foregoing comments would be appreciated and any reply you care to make would be welcome.

The following people attended and commented on the 7 May 1970 meeting.

David J. Allee	Office, Secretary of the Army
W. E. Butler	North Atlantic Division
Jerome Degen	Anderson - Nichols & Co. (NAD)
John J. Curry	Water Resources Commission (Conn.)
Louis I. Jones	Office of the Chief of Engineers
Lt. Col. R. R. Werner	Office of the Chief of Engineers
Bob Meiklejohn	North Atlantic Division
Malcolm E. Graf	New England River Basins Commission
Mark Abelson	Department of Interior
Paul Pronovost	New England Division
Joseph L. Ignazio	New England Division
John Wm. Leslie	New England Division
Allan Grieve, Jr.	Metropolitan District Comm. - Water Div.
John W. Copithorn	Metropolitan District Comm. - Water Div.
Leonard J. Fenochetti	Metropolitan District Comm. - Construction Div.
Louis H. Carnfel	Mass. - Division Fish and Game
James J. Matera	Metropolitan District Comm. - Water Div.
Charles H. W. Foster	Boston
Carl N. Shuster, Jr.	U. S. Public Health Service
Frank Grice	Mass. Dept. Nat. Res. - Div. Marine Fish
W. Leigh Bridges	Mass. Dept. Nat. Res. - Div. Marine Fish
Emerson H. Chandler	Mass. Division of Water Resources
O. F. Pyle	Mass. Division of Water Resources
Clinton E. Watson	Mass. Division of Water Resources
Terrence P. Frost	N. H. Water Supply & Pollution Control Comm.
Daniel Collins	N. H. Water Supply & Pollution Control Comm.
George J. Coogan	Mass. Department of Public Health
Martin Cosgrove	Metropolitan District Comm. - Construction Div.
James J. MacKenzie	Union of Concerned Scientists, MIT
Allen H. Morgan	Massachusetts Audubon Society
Deborah V. Howard	Massachusetts Audubon Society
Charles F. Kennedy	Mass. Water Resources Commission
Harry E. Schwarz	Corps of Engineers (North Atlantic Division)
Frank McGowan	Corps of Engineers (North Atlantic Division)
Henry Monroe	R. I. Water Resources Board
George McGee	N. H. Water Resources Board
Floyd Taylor	USPHS & NERBC Water Supply Comm.
Mario Borschetti	Mass. Department of Public Health

4. Progress Meetings

Throughout this study, a determined effort has been made to inform the public of the work's progress. Ten progress meetings were held in the Boston Metropolitan area, generally at the Corps' Waltham, Massachusetts office. Technical progress on the various elements of the NEWS Study was described by the study team. Usually attendance was about 50 people, representing Federal and State agencies, conservation and sportsmen groups, and interested citizens. In this informal atmosphere, questions, answers and opinions were exchanged between the study team and the audience. The information gained at these meetings greatly influenced the direction of the study and the final recommendations.

The first of these meetings was held on 7 May 1970, then at intervals of about 2 months with the latest held on 7 June 1972. A typical agenda follows:

NEWS Progress Meeting
New England Division, Corps of Engineers
4 March 1971

AGENDA

I Introduction - J. L. Ignazio

II Study Progress in New England

A. General

B. Tully

1. Potential Service Areas & Water Demands
2. Potential Donor Tributary Studies
3. Transmission Conduit Route Studies
4. Water Quality Studies

C. Northfield Mountain

1. Water Quality and Ecological Studies
2. Public Health Service Studies

D. Merrimack River Study

1. Service Areas and Water Demands
2. Review of Ongoing Studies - Synopsis
3. Potential Reservoir Site Screening
4. Hydrologic System Analysis

E. Ecological Studies

1. Connecticut River Estuary
2. Merrimack River Estuary

F. Advanced Land Acquisition

III Open Discussion

IV Other Business

5. Formulation Stage Public Meetings

A. General

In order to broaden public participation in the study, a series of four formulation stage public meetings were held in Needham, Woburn, Orange, and Longmeadow, Massachusetts, during December 1971 and January 1972. The on-going studies were described, including preliminary alternatives and the audience was given a chance to comment on this work and suggest any other ideas. This input received was considered in the formulation of all plans presented in this report. Digests of each of these public meetings follow:

B. Digest of the 15 December 1971 Public Meeting of the NEWS Study At Needham, Massachusetts

1) Colonel John H. Mason, Deputy Division Engineer, New England Division, presided at the public meeting attended by some 50 people.

2) The following is a digest of the major speakers' presentations:

a) Colonel Mason delivered the opening remarks, introducing any elected officials present and representatives from the Commonwealth of Massachusetts and from the Corps. Also, he explained the purpose of this formulation stage public meeting which was to present results of our studies to date and to received public reactions to these developments.

Colonel Mason then summarized the background and goals of the study. He explained the broad scope of the law and that only the New England portion of the study would be discussed at this meeting. There were five major elements of work within the New England Division. The first is the analysis of the use of the Tully Reservoir Complex for water supply with appropriate transmission to Quabbin Reservoir. Second, the consideration of the Northfield Mountain development as a water supply source for Southeastern New England. Third, studies of the requirements to improve the water quality of the Merrimack River and to use the river as a possible water supply source. Broad environmental and ecological studies of the Connecticut and Merrimack estuaries are the fourth part of the New England studies. Fifth is the identification and assessment of social, legal and economic implications of acquiring lands for water resource development far in advance of construction.

In closing, Colonel Mason described the public participation in the NEWS Study to date, which included seven informational public meetings within the New England area and a series of seven progress meetings held at our Waltham office. Participants at these progress meetings include representatives from federal, state and local agencies as well as from local interest groups, such as the League of Women Voters, the Audubon Society, watershed associations and community conservation groups.

b) Mr. Harry E. Schwarz, Chief, Special Studies Branch, North Atlantic Division, who is responsible for the entire NEWS Study, gave an overview of the whole study. He explained that the study, which covers the drainage areas of Chesapeake Bay, the Atlantic Ocean north of Chesapeake Bay, the St. Lawrence River and Lake Ontario, found four large areas having critical needs within the next ten years. These were: Eastern Massachusetts and Rhode Island; Western Connecticut - Metropolitan New York - Northern New Jersey; Southcentral Pennsylvania - Metropolitan Baltimore; and the District of Columbia. Since the meeting concerned the Southeastern New England area, he only spoke about the other three areas. In the Western Connecticut - Metropolitan New York - Northern New Jersey area, they are presently evaluating a series of projects identified in an engineering feasibility study to determine the better schemes for further, more detailed study. In the Southcentral Pennsylvania - Metropolitan Baltimore area, Baltimore was found not to be an urgent area; so only a feasibility study of Southcentral Pennsylvania is continuing. In the Washington D. C. area, an engineering feasibility report has been completed and is now being reviewed to determine the next step in the area.

c) Mr. Paul Pronovost, Study Manager, NEWS, Southeastern New England Area, New England Division, then summarized the work under way and how it relates to meeting the future water needs of the area. First, he illustrated the communities who were expected to need additional supplies by the year 1990. If these communities joined the existing Quabbin-Wachusett-Sudbury system (MDC) then this system would have to be supplemented by the mid 1980's. Three projects are under investigation presently. Two of these projects, Northfield Mountain and Millers River Basin, are survey scope studies. The third investigates the possibility of diverting water from the Merrimack River as a water supply source for Eastern Massachusetts.

In the Northfield Mountain Water Supply Project, a small portion of the annual spring run-off from the Connecticut River would be diverted via the pumped storage hydroelectric facility at Northfield Mountain to

Quabbin Reservoir. Recognizing that this project has been authorized for construction by the Commonwealth of Massachusetts, the NEWS studies are designed to complement those of the State. With the addition of 72 MGD safe yield from Northfield Mountain, communities identified as water short and feasibly serviced by the system could meet their needs through the year 1983.

To meet the short-range target year of 1990, therefore, some additional supply must be made available. The second project being considered is a number of combinations of diversions from the Millers River Basin. The additional 46 MGD yield from this system with Northfield Mountain would meet the demands of the expanded service area through 1990.

A number of slides were then shown to illustrate the effect of both diversions on Priest Brook, one of the tributaries which might be diverted, on the Millers River and on the Connecticut River. An explanation of what is being studied with regard to the impacts of the projects on the environment was made. This included discussions of two contracts awarded to firms to investigate the effects of the diversions on the rivers and on the reservoirs and on the Connecticut River estuary. Also, studies are being performed to identify and assess the socio-economic effects of the potential water supply development.

The third study discussed was the feasibility investigation of the Merrimack River. The objective being to evaluate the requirements for improving the water quality of the river and to make a detailed investigation of its use as a long-range water supply source for Eastern Massachusetts region. Water would be diverted from the Merrimack River in the vicinity of Lowell, Massachusetts, treated in a water treatment plant and then pumped through aqueducts to service communities. In these investigations, particular emphasis is being placed upon determining the compatibility of any diversion with other uses of the river such as recreational development and the anadromous fish restoration program.

The final element of study under investigation by the NEWS Study is the identification and assessment of social, legal and economic implications of acquiring lands for water resources development projects in advance of construction. It is planned to initiate this work in January 1972.

In summary, Mr. Pronovost explained that all the diversions contemplated would use the high flow skimming techniques; that is, use of what we believe to be excess flows which occur naturally in this area about one quarter to one third of the year.

d) Mr. Charles F. Kennedy, Director and Chief Engineer, Massachusetts Water Resources Commission, spoke on behalf of Dr. Charles Foster, Secretary of Environmental Affairs, Commonwealth of Massachusetts. He stated that the recent drought of the 1960's and the ever-increasing pressure of water use and demand in some instances is threatening and in many cases actually has exceeded the capacity of our existing water supply system. By the time the drought was over, restrictions on water use had been imposed in over 100 of the Commonwealth's 351 cities and towns, and emergency water supplies had been required in more than 50 municipalities. There is no question that large new sources of water must be made available soon, nor that these must be surface water sources. Mr. Kennedy explained the Commonwealth's participation has been in the form of direct involvement with the Corps in the NEWS Study. Two elements of the study, referred to as the Northfield diversion and the Tully diversion, have been endorsed in principle by the Water Resources Commission. The Commonwealth of Massachusetts, through its resource agencies, will continue to work closely with the Corps of Engineers towards a coordinated successful completion of the NEWS Study.

e) Mrs. George H. Williams, Boston Coordinator for the New England Coalition on Nuclear Pollution, expressed concern that the Vermont Yankee Nuclear Power Plant might pollute the Connecticut River, affecting the diversion from Northfield Mountain for water supply.

f) Mr. Martin F. Cosgrove, Deputy Engineer, Metropolitan District Commission, Construction Division, commented on the potential problem with Vermont Yankee. He stated that the Commonwealth of Massachusetts will insist that there be a number of lines of communication between the Vermont Yankee Plant and Federal and state agencies involved in water supply; so if an accidental spill occurs, we will be able to stop diversion until the radioactive levels become acceptable again. We feel with this line of communication and a monitoring system, we have enough safeguards to protect the water supply of Metropolitan Boston.

g) Dr. Jerome Carr, Lowell Technological Institute, Research Foundation, felt that the study should investigate groundwater sources since they are underdeveloped in this area.

3) After the major speeches had been made, questions were asked concerning the NEWS Study either from the floor or submitted on cards. The following is a summary of the questions and answers:

a) A question was asked why we cannot modify water demand by 1990.

Assuming that we can overcome the social and political problems associated with controlling water use, the expected results in savings would not preclude the need for new water supply sources.

b) How does the MAPC report on alternative local regional water supplies sources affect your projected demand on the MDC system?

We used this report extensively in our studies to determine demands. Any feasible local supply source was assumed to be used before the city or town would join the MDC.

c) Is there a clear MDC commitment to clean the Merrimack River water by 1990 and will this meet all projected demands?

The Merrimack appears to be the most likely next step, but it will not meet all the water demands of the area forever.

d) Would it be possible to divert Millers River water at a point close to Quabbin Reservoir?

The Millers River is a highly polluted source and even with treatment there are sludge deposits in the river which affect the quality. Because we have to see how the river reacts to clean-up, we are unable to look upon it as an immediate water supply source. However, once we can answer these quality questions, then it may offer a good solution.

e) What steps are being taken to protect the existing water supply systems?

In our studies, we are assuming that all these existing systems are to be maintained and stay on line. No one is suggesting abandoning your small systems and use them for recreational lakes.

4) At 11:05 p.m., the meeting was closed.

C. Digest of the 16 December 1971 Public Meeting of the NEWS Study At Woburn, Massachusetts

1) Colonel John H. Mason, Deputy Division Engineer, New England Division, presided at the public meeting attended by some 40 people.

2) The following is a digest of the major speakers' presentations:

a) Colonel Mason delivered the opening remarks, explaining the purpose of the meeting and summarized the background and goals of the study as he had done the night before in Needham, Massachusetts.

b) Mr. Frank McGowan, NEWS, North Atlantic Division, gave an overview of the whole NEWS Study similar to Mr. Schwarz's speech at Needham, Massachusetts.

c) Mr. Paul Pronovost, Study Manager, NEWS, Southeastern New England Area, New England Division, then summarized the work under way and how it relates to meeting the future water needs of the area. His speech was the same as the one given in Needham.

d) Mr. Charles F. Kennedy, Director and Chief Engineer, Massachusetts Water Resources Commission, explained the Commonwealth's role and interest in the NEWS Study as he did in Needham.

e) Mr. Martin F. Cosgrove, Deputy Chief Engineer, Metropolitan District Commission, Construction Division, stated the involvement of the MDC in the NEWS Study. The MDC is authorized to divert water from the Connecticut River to Quabbin Reservoir through the Northfield Mountain Pumped Storage Facility. The MDC has no authorization to divert water from either the Millers River Basin or the Merrimack River. However, we recognize both of these watersheds as potential water supply sources for the Boston Metropolitan Area.

f) Honorable Edward F. Gill, Mayor, Woburn, Massachusetts, believed that the whole subject of water supply in the United States is treated too lightly. Maybe it is because water is too cheap and it is just human nature that we cherish lightly what we buy cheaply. He felt in order to correct the situation, Congress should create a regional authority to control and distribute all of the water resources of this area.

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g) Mr. Edward Crowley, Alderman, Woburn, Massachusetts, discussed the problems he faces with urbanization of the watershed. In particular, he was concerned with the filling of wetlands and swamps for the construction of apartment houses and industrial development. He felt that this development was endangering the potential water supply sources for Woburn.

h) Mr. Elliot C. Farwell, Woburn Conservation Commission, felt that more emphasis should be placed on the conservation of water, especially by improving plumbing fixtures.

i) Mr. William J. Ginevicz, Woburn Conservation Commission, was concerned with the setting aside greenbelts along streams to protect them. In that way, the streams could be used for a separate water supply system to be utilized by industry and for fire protection.

3) After the presentations by the major speakers, the floor was open to questions. The following is a summary of those questions and answers:

a) What is the feasibility of underground natural holding areas instead of surface reservoirs?

In the NEWS Study, we investigated these natural holding areas to determine the extent of the groundwater aquifers in this area. It does not seem feasible in this area to increase the underground storage retention areas because we have Quabbin Reservoir, which is not being used to capacity. None of our possible solutions include additional large storage reservoirs anyway.

b) Is distillation a feasible method of recovering polluted water?

Distillation is one of the methods investigated and it was found to be a very expensive way of doing it.

c) Has any consideration been given to the possible recreation potential given to Tully Reservoir?

Yes, we will incorporate recreational plans into the reservoir. Normally, water contact sports are not allowed in water supply reservoirs, but because of the special circumstance where the water supply and recreation uses would not occur at the same time, recreation is allowed.

4) At 10:30 p.m., the meeting was closed.

D. Digest of the 11 January 1972 Public Meeting of the NEWS Study At Orange, Massachusetts

1) Colonel John H. Mason, Deputy Division Engineer, New England Division, presided at the public meeting attended by some 175 people.

2) The following is a digest of the major speakers' presentations:

a) Colonel Mason delivered the opening remarks explaining the purpose of the meeting and summarized the background and goals of the study as he had done at the Needham and Woburn public meetings.

b) Mr. Harry E. Schwarz, Chief, Special Studies Branch, North Atlantic Division, gave an overview of the whole NEWS Study, similar to the one given in Needham.

c) Mr. Paul Pronovost, Study Manager, NEWS, Southeastern New England area, New England Division, then summarized the work under way and how it relates to meeting the future water needs of the area. His speech was the same as the one given in Needham and Woburn.

d) Mr. Charles F. Kennedy, Director and Chief Engineer, Massachusetts Water Resources Commission, explained the Commonwealth's role and interest in the NEWS Study as he did at Needham and Woburn.

e) Mr. H. Thomas Colo, State Representative, Athol, Massachusetts, felt that unfortunately the conclusion has already been arrived at that the water will be taken. This information gathering process that is taking place tonight is more of a defusing process. He ended by hoping that we would reverse the steps taken and put the technology and the efforts toward water conservation.

f) Mr. Martin F. Cosgrove, Deputy Chief Engineer, Metropolitan District Commission, discussed a preliminary report to the state legislature concerning new sources of water supply for the MDC. The MDC has determined that the next step in the expansion of water sources will be the Northfield Mountain water supply project. The second step would be diversions from the Tully River. Third, the yield from the existing Sudbury system would be increased by flood skimming. Finally, there are other sources of supply to be investigated for use beyond the year 2000, including the Merrimack River.

g) Mr. Leo J. Dugas, Chairman of the Board of Selectmen, Athol, Massachusetts, stated that the Town of Athol feels the Tully Complex plan as presented is unacceptable and that we should concentrate on raising the classification of the Millers River to a point where it would be acceptable for diversion.

h) Mr. William Simmington, Jr., Selectman, Town of Royalston, Massachusetts, was concerned that his town would lose valuable land under the Tully Complex proposal. He thought that some form of compensation in the way of taxes should come back into the town. He had no doubt that eastern Massachusetts is going to get the water because most of the legislature probably belongs to the MDC system.

i) Mrs. Joan Ashwell, Citizens Participation Group, explained that the group is made up of conservationists, state and local officials and representatives from industry in the Millers River Basin. They hope to present a unified report of our comments, opinions and feelings of the Millers River Basin people.

j) Mr. Thomas Bailey of Athol, Massachusetts, felt that the basic problem is one of population and conservation of water resources. However, realizing that the western part of the state is stuck supplying Boston with water, the money should be spent to clean up the Millers River and then divert from that river.

k) Mr. Raymond M. Higgins, Coalition for Environmental Quality, University of Massachusetts, read a position statement of the group. It stated that the natural effects of out-of-basin water diversion are undesirable. The decrease in the water volume in the source basin and the altered flooding and attendant natural processes, harm that basin's ecological systems, and the deterioration which results, over time, becomes serious.

l) Mr. Joseph Ellinwood, Chairman, Athol Water Study Commission, was in favor of having the user pay the basin communities for the water taken because of the fantastic problems caused by the construction of Quabbin Reservoir. He further stated that he was opposed to the diversion of any water from the Millers River Basin and we should concentrate on study diversions from the Connecticut, the Merrimack and the Androscoggin Rivers.

m) Mr. Robert L. Gray, Chairman, Millers River Watershed Council, Inc., spoke in favor of diverting water from a cleaned-up Millers River, instead of from the Tully Complex.

n) Mrs. Jane Brower, New England Chapter of the Sierra Club, suggested that Supreme Court decision concerning Quabbin Reservoir releases be reviewed. Also, the alleged practice of flushing the Charles River periodically with MDC water should be stopped. Thirdly, failure to meter fully and to charge adequately for the water supplied contributes vastly to waste.

o) Mr. Rizerio John DeLeo, Athol, Massachusetts, suggested that if the people of the Boston area need water, why not move out to this area where there is plenty of clean, fresh water.

p) Mr. Harry E. Seymour, Athol, Massachusetts, thought that the solution to the water supply problem is conservation, not construction.

q) Mrs. Janice Corser, Royalston, Massachusetts, said she could not see how the Corps could recommend the Tully Complex when tonight no one has spoken for the project.

3) Then the floor was open to questions. The following is a summary of the questions and answers:

a) How can we stop this project?

The Corps of Engineers does not do anything without Congressional funding and state support. Also, we have stated tonight this is a formulation stage public meeting and we have not made any recommendations.

b) How will the pollutants in Connecticut River water effect the quality of Quabbin's water?

This is one area that will be fully responded to when the ecological studies are completed.

c) What is the possibility of changing the Supreme Court decision to modify downstream releases from Quabbin?

I think that you have to realize that the Supreme Court probably would have to rule on the case again. The amount of water in question is in the neighborhood of 35 million gallons a day.

d) If you remove a large percentage of water from the Millers River, won't it increase the odor from the river?

You have to bear in mind that water quality problems such as odors occur in the dry weather periods of the year, not in the spring freshet when diversions would occur.

e) What about studies of water use?

We are doing some studies on what the water is used for and how it is used. The reduction of water use is a widespread social problem far more than an engineering problem.

f) What causes the increased water consumption?

One reason that water consumption is increasing in the Boston area on a per capita basis is that more and more people are coming to Boston to work or to go to school and they are not part of the permanent population. Yet, they use MDC water.

g) How can you spend millions on a system which would operate on an undependable flow basis?

The yield values are based on the long-term average of diversion over the period of record, so there is a dependability to the number given.

h) Is a water treatment plant on the Charles River in anyone's plans?

To my knowledge, there are no plans for such a plant.

4) At 11:55 p.m., the meeting was closed.

E. Digest of the 12 January 1972 Public Meeting of the NEWS Study At Longmeadow, Massachusetts

1) Colonel John H. Mason, Deputy Division Engineer, New England Division, presided at the public meeting attended by some 40 people.

2) The following is a digest of the major speakers' presentations:

a) Colonel Mason, as he had done at the previous meetings, delivered the opening remarks explaining the purpose of the meeting and summarized the background and goals of the study.

b) Mr. Harry E. Schwarz, Chief, Special Studies Branch, North Atlantic Division, gave an overview of the whole NEWS Study, similar to the ones given in Needham and Orange.

c) Mr. Paul Pronovost, Study Manager, NEWS, Southeastern New England Area, New England Division, then summarized in the same manner as previous meetings the work under way and how it relates to meeting the future water needs of the area.

d) Mr. Charles F. Kennedy, Director and Chief Engineer, Massachusetts Water Resources Commission, explained the Commonwealth's role and interest in the NEWS Study as he had done at the previous meetings.

e) Mr. Stanley H. Williamson, New Hampshire State Representative, felt that more emphasis should be placed on environmental considerations and costs. Too much emphasis is being placed on short range solutions, long range solutions such as desalination, recycling for industry and conservation of water in the home.

f) Mr. L. P. Johnson, Executive Engineer, Metropolitan District, Hartford, Connecticut, spoke concerning the district's need of the Connecticut River as a long range water supply source. They felt that the Federal Government should accept jurisdictional authority for minimum flow provisions and low-flow augmentation and provide a forum through the New England River Basin Commission for water allocation in recognition of the riparian rights of all the people utilizing the river.

g) Mr. William Neal MacKenzie, President, Connecticut Water Company, Clinton, Connecticut, represented the third largest investor owned water company in the State of Connecticut, supplying more than 6 billion gallons last year to 150,000 people. He hoped that action toward advance land acquisition of reservoir sites would be taken in the near future especially by the state. In these plans, there should be no discrimination between municipally owned and investor owned utilities. He supports the efforts of the Corps in planning to meet the future water supply requirements of the Northeast region and pledged his company's cooperation in arriving at the most satisfactory and economical solution to the many problems involved.

h) Mr. Frank C. Olbris, Florence, Massachusetts, as a resident of the basin, objected to the tapping of the basin's resources to further the growth of Boston. He suggested that user charges,

metering, rationing, and other rather stern social disciplinary measures be extensively studied and implemented in stages as methods of dealing with Boston's growth problem.

i) Mr. Robert H. Reinert, Assistant Vice President, Bridgeport Hydrolic Company, stated that his company which serves some 400,000 people in the Greater Bridgeport area, found that the Connecticut River must ultimately supply Connecticut. He was most concerned with the proposed diversions from the Connecticut River Basin because of flood skimming in Massachusetts will tend to preclude similar flood skimming in Connecticut. The needs of Eastern New England should be first met by developing the rivers of Eastern New England.

j) Mr. Joseph A. Novaro, Vice President - Engineering, New Haven Water Company, expressed his company's concern with protecting its interest in the Connecticut River as a supply source and wishes to participate in the planning for the regional development of this source.

k) Mr. Lee Lyman, Director of Research, Water Quality Laboratories, Wellesley Hills, Massachusetts, felt that water diverted from the Connecticut River will add toxic compounds to Quabbin Reservoir which will be biologically magnified up through the food chain. He suggested that more research be accomplished to determine the extent of the problem.

3) Then the floor was open to questions. The following is a summary of the questions and answers:

a) What assurances do we have that minimum diversion rates will not be increased by future legislature's action?

If it is a Federal project, authorization carries limitations enforceable by law and can only be changed by Congress.

b) Can land already acquired by the State for other purposes be used for water supply reservoirs?

Yes, but it would require an Act of the Legislature.

c) What are the potential water supply sites for Western Massachusetts?

We have looked at all of the possibilities that may exist for the communities within the study area and maps and other pertinent information is available at any time. There are so many combinations that time does not permit going through them all.

d) What areas have good ground water supplies?

We have utilized the work done by the U. S. Geological Survey which pointed out on large groundwater sources in Plymouth County.

e) What about reducing demand?

We have looked at technologies to reduce demand. However, they are most difficult and concerned as possible long range solutions.

4) The meeting was closed at 10:40 p. m.

6. Citizens Participation Board

In December 1971, at the request of a number of Millers River Basin citizens, a 13-member citizens group was formed. The purpose of this Board was to act as an ombudsman for the citizens of the Millers River Basin. They arranged informational meetings, collected questions concerning the study, reviewed our work, formally represented the people of the Millers River Basin at meetings and generally kept the Basin residents informed of the study's progress. The Board members, with one exception, were located in or near the Millers River Basin and as such were mainly interested in the Millers River Basin Water Supply Project portion of our study. The following is a list of those members:

Mrs. Joan Ashwell of Orange, Co-Chairman
Chairman, Orange Conservation Commission

Mr. Robert Gray of Athol, Co-Chairman
Chairman, Millers River Watershed Council

Mr. Warren Sinclair of Gardner
Citizens Review Committee for New England River Basins Commission

Mrs. Florence Carver of Amherst
Citizens Review Committee for New England River Basins Commission

Mr. Thomas G. Simons of Montague
State Representative

Mr. Henry Waidlick of Montague
Selectman, Town of Montague

Mr. Fred Muehl of Colrain
Franklin County Planner

Mr. Paul Mallet of Athol
Employed by Erving Paper Mills

Mr. William Thorpe of Athol
Employed by the L. S. Starret Company

Mr. George Pushee of Templeton
Member of the Millers River Watershed Council

Mr. Duane Leonard of Templeton
Member of the Millers River Watershed Council

Mr. Allan Hawk of Orange
Member of the Orange Conservation Commission and the Orange Planning Board

Col. George Baker of South Royalston
Member of the Millers River Watershed Council

7. Informational Meetings

In addition, four informational meetings were held within the Millers River Basin. These informational meetings were held in Athol, Massachusetts, on 21 October 1971 and 4 January 1972; and in Winchendon, Massachusetts, on 2 March 1972; and in Athol, Massachusetts, on 8 May 1972. Local government or citizens' groups requested these meetings, offering a further opportunity for public understanding and participation in the study.

At these meetings, we summarized our studies to date, emphasizing the Millers River Basin Study and then responded to questions. Questions covered a wide range of areas and usually took most of the time allotted. The general reaction of the local people was that they were concerned with trade-offs in assisting the Boston metropolitan area in meeting its water supply needs as they cannot see how their watershed will benefit. There was not the usual concern for the environment, but rather a bread and butter approach to cutting back flows. They felt that diversions would dry up the Millers River flows which are badly needed for their water supply and pollution abatement. This type of discussion assisted in developing the most advantageous alternative.

8. Late Stage Public Meetings

A. General

Two late stage public meetings were held in Waltham and Orange, Massachusetts, in July 1972. Results of the NEWS investigations were described and the advantages and shortcomings of the alternative proposals were outlined and discussed at these meetings. Digests of those two meetings follow:

B. Digest of the 5 July 1972 Public Meeting of the NEWS Study At Waltham, Massachusetts

1) Colonel John H. Mason, Deputy Division Engineer, New England Division, presided at the public meeting attended by some 50 people. A complete list of those who signed attendance cards is attached.

2) The following is a digest of the major speakers' presentations:

a) Colonel Mason delivered the opening remarks, introducing any elected officials present and representatives from the Commonwealth of Massachusetts and from the Corps. He then summarized the background and goals of the study. He explained the broad scope of the law which is to prepare plans to meet the long-range water supply needs of the Northeast in cooperation with Federal, state and local agencies. However, at this meeting, only the five major elements of work within the New England area were discussed. The first element is the investigation of the Millers River Basin potential as a supply source. Second, is the consideration of the Northfield Mountain development as an element of any regional water supply plan for Southeastern New England. The third studies the requirements to improve the water quality of the Merrimack River and its use as a possible water supply source. Fourth is the broad environmental and ecological studies of the Connecticut and Merrimack Rivers, including their estuaries to determine the impacts of any diversion. Fifth is the identification and assessment of social, legal and economic implications of acquiring land for water resource development in advance of construction.

Colonel Mason ended by explaining the broad public participation in the NEWS study sought. This participation took the form of seven public meetings held in New England in 1967, four formulation stage public meetings held in December 1971 and January 1972, and nine progress meetings over the past two years as well as a number of informal information meetings.

b) Mr. Charles F. Kennedy, Director and Chief Engineer, Massachusetts Water Resources Commission, spoke on behalf of Dr. Charles H. W. Foster, Secretary of Environmental Affairs, Commonwealth of Massachusetts. He explained the coordination between the State and the Corps stating that with the exception of the Northfield Mountain diversion, no final decisions, approvals or commitments have been made by the State. The Water Resources Commission endorsed in 1970 the proposal to divert flood flow from the existing Tully Reservoir; however, it does not approve of Alternative No. 3, which would divert upstream subsidiary drainage into Tully Reservoir. Also, in 1970, the Commission stated that if diversion from the mainstem of the Millers River became practical, then this proposal should be reconsidered. Obviously, this proposal has been seriously reconsidered by the NEWS Study as evidenced by Alternative No. 2, Tully-Millers River diversions.

Mr. Kennedy questioned the credibility of the so-called open planning process; however, the evidence convinced him that this process can work. Not too long ago, it seemed that the objective of the NEWS Study

was Alternative No. 3, Tully Complex. But, this open planning process involving private citizens, local, state and Federal officials, provided dialogue to re-examine the options and alternatives and resulted in Alternative No. 2 being the most advantageous project for the supplier and receiver areas.

He indicated that this alternative was more compatible with the state's water planning philosophy than the other two alternatives, but suggested that other options such as desalination, waste water reuse, pricing policies, etc., while not immediate solutions, should not be ignored.

c) Mr. Paul E. Pronovost, Study Manager, NEWS, Southeastern New England, made the technical presentation describing the background of the study team, the problem areas, alternative solutions and our conclusions. He explained that many skills and disciplines were necessary in this study, including biologists, environmentalists and engineers. The reason for this study is that along with a dramatic increase in population, the water demands in the area are also expected to increase twofold by 2020. Communities which may have water supply shortages by 1990 were delineated and include the largest system in the area, the Metropolitan District Commission. To meet these shortages, three plans are being studied: the Northfield Mountain and Millers River Basin survey reports for the 1990 needs and the feasibility of diverting from the Merrimack River as a long-range source for Eastern Massachusetts.

The Northfield Mountain project would divert a small portion of the annual spring runoff from the mainstem Connecticut River via the Northfield Mountain Pumped Storage project to Quabbin Reservoir. Because the project has been authorized for construction by the Commonwealth of Massachusetts, the NEWS studies are designed to complement the MDC work. However, even with the addition of the Northfield supply, the estimated water needs of the area could only be met through 1983.

To meet the short-range target year of 1990, an additional supply source must be made available. Three alternative methods of developing the Millers River Basin appear to have merit. These are Alternative No. 1 - diversion from only the mainstem Millers River; Alternative No. 2 - diversion from the mainstem Millers River as well as the East Branch Tully River; and Alternative No. 3 - diversions from Tarbell and Priest Brooks and from the East and West Branch Tully Rivers, called the Tully Complex. Alternative No. 1 would include advance waste treatment facilities on the upstream point sources of pollution. Based on economics,

this alternative presents an attractive solution to the future water supply problems. However, questions remain on the water quality of the Millers River even after this additional waste treatment. To answer these questions fully, the river's natural reaction to the clean-up must be observed. The risk that even with the clean-up, the river quality may still not be suitable for diversion was carefully considered in evaluating the alternatives. With this alternative, positive environmental and socio-economic impacts within the basin should be realized because of a clean Millers River. Alternative No. 2 would divert water from the Millers River as in Alternative No. 1, but would also divert East Branch Tully water from the outlet channel of the existing Tully Flood Control dam. The use of this alternative has similar economic, environmental and socio-economic impacts as Alternative No. 1. In addition, the availability of good quality East Branch Tully River water considerably decreases the risk involved in Alternative No. 1. The single disadvantage is the possible environmental impact on the Tully River which our investigations to date have revealed as minimal. Finally, these questions on the use of the Millers River mainstem prompted the Corps to investigate the possibility of diversions from the Millers River tributaries -- Alternative No. 3. The major advantage of this plan is the good quality of the water. However, there are several disadvantages: (1) it is the most expensive; (2) the potential yield is less than either of the other two alternatives; and (3) possible socio-economic and environmental impacts are greater than with Alternatives No. 1 and 2. On the basis of our investigations, it was concluded that the most advantageous plan for the communities of the basin and those municipalities which would use the water is Alternative No. 2.

Concerning the Merrimack River Study, a number of regional planning commissions have been active in developing water supply plans and have indicated further development of the Merrimack as a potential source. Particular emphasis in our work is being directed towards determining the compatibility of any diversion with other proposed uses of the river, such as recreational development, anadromous fish restoration programs, and other allied water uses. Work on the Merrimack's potential continues and the report will be written later in 1972.

The last element under investigation involves the identification and assessment of social, legal and economic implications of acquiring land for water resource projects becomes obvious in view of the growing demand for undeveloped land. A report on the pros and cons of this method is due for completion in November of 1972.

Mr. Pronovost ended by summarizing the five elements of study, including less traditional techniques such as desalinization, waste water reuse and pricing impacts on demand.

d) Mrs. Rita Barron, Water Resources Chairman, Massachusetts League of Women Voters, stated that the League has long supported long-range comprehensive planning and demanded a role for the citizen in the decision-making process. The Northeastern United States Water Supply Study has provided such a planning program. She addressed herself to three basic needs -- those of the MDC constituency, those of Quabbin Reservoir and those of the Connecticut Valley. They felt that the Corps has attempted to deal as reasonably as possible with the overall impact on the Connecticut River, particularly Northfield. Regarding the Millers River Basin alternatives, they were relieved that Alternative No. 3 appears to be out of serious consideration. Cleaning up the Millers River was felt to serve the whole state. Maintaining the environmental integrity of Quabbin Reservoir itself was seen as a social and economic benefit to all. The MDC has produced a hydrologic wonder in its water system, but it is felt to be seriously out of order in the development of fiscal and social responsibility among its customers. They don't question the needed expansion of the system, but that it should be accompanied by high-level state commitment to responsible management of the water resources of Massachusetts.

e) Mr. Bruce L. Lund, Sanctuary Director, Massachusetts Audubon Society, stated as an interested citizen that the plans presented probably were the best economically, environmentally and efficiency-wise to do a "crisis" job. However, they stop short of the real problem -- reducing demand. He felt that the Corps had worked as hard on the social, economic and other areas as well as the engineering in this study and should tackle this problem along with the engineering ones. He recommended the following alternatives be instituted before any construction begins:

(1) Regulation of consumption -- a community gets a limited amount of water.

(2) Water rate charges -- the larger uses should pay more per unit for more water used.

(3) Water recycling -- especially in industry.

(4) Population zoning -- restrict population and industrial growth in a certain area.

f) Mr. George H. Wallace, Chairman, Natick, Massachusetts, Conservation Commission, suggested four possible alternatives:

(1) Implementation of a strenuous education program leading towards the wiser and more realistic future use of our water resources.

(2) Create building codes forcing the use of water saving devices.

(3) Tax incentives for industrial reuse and purification equipment.

(4) Implement immediately a parallel Corps of Engineers study to evaluate and effectuate comprehensive water use controls.

g) Mrs. Celeste McQuillan, Secretary, Save Our Streams, read the statement of her organization which stated they were opposed to any diversion from the Millers River Basin. They cited the following reasons:

(1) Flood waters are necessary to the life cycle of the river and are not waste waters.

(2) We do not need a Class A river because it is restricted solely to water supply and we need a recreation river.

(3) The alternatives of conservation, recycling and desalinization have not been fully exhausted.

(4) The MDC should stop its westward movement and concentrate on the Merrimack and Charles Rivers.

A diversion cannot be labeled necessary, they felt, simply because a river needs to be cleaned or because the ineptitude of the MDC in the area of conservation of water.

h) Mrs. Joan Ashwell, Co-Chairman of the Citizens Participation Group for the NEWS Study, stated that the group is opposed to any of the Millers River Basin alternatives at this time. They felt that several serious questions had to be answered, details worked out and commitments made, especially by the State before diversion could be approved. While the Corps of Engineers has been open to suggestions and willing to discuss all aspects of the plans with the public, she stated that the State Agencies involved have taken little interest in discussing the study. Mrs. Ashwell ended by listing a number of problems the State must make decisions on now.

i) Mr. Robert L. Gray, Chairman, Millers River Watershed Council, Inc., stated that this group, representing the 17 cities and towns within the Basin favored Alternative No. 1 because the donor area would receive a clean stream and the receiver area would get more water, carried a shorter distance, at the least expense. Also, if any other plan is recommended, they would be forced to advocate no diversion at all.

j) Mr. Francis T. Bergin, Chief Engineer, Construction Division, Metropolitan District Commission, Boston, Massachusetts, stated that the MDC has no authorization to divert water from the Millers River or Merrimack River Basins other than the existing operating system in the Wachusett and Sudbury Reservoirs. They do recognize these sources as well as the state authorized Northfield Mountain project as future sources of supply. He ended by offering to answer any questions that anyone had concerning the MDC.

3) Following the speakers, the floor was open to questions. The following is a summary of those questions and answers:

a) Has a route for the proposed Merrimack tunnel from Lowell to Boston been decided upon?

There has been no actual designation of that route. However, we have looked at using the median strips of highways and will look at the old Middlesex Canal route.

b) What has happened to the Abt Associates report?

That report is in draft form now, but is available in our office for review by anyone.

c) In data handed out, why were the words "Generally, principally, mainly in the spring" used to describe the diversion period?

This is because the Millers River Basin diversion periods are based on meeting certain control flows. When these are exceeded, then diversions would occur. The majority of the time this would be during the springtime. However, occasionally there would be a period of diversion during the fall.

d) How can the entire state benefit from these diversions?

Well, simply the fate of the eastern part of the state certainly will effect the western part of the state. Also, the socio-economic impacts

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on the donor area appear to be small. The biggest thing appears to be the supplier towns moral outrage at being "forced to give up our water."

4) The meeting was closed at 10:30 p.m.

C. Digest of the 6 July 1972 Public Meeting of the NEWS Study At Orange, Massachusetts

1) Colonel John H. Mason, Deputy Division Engineer, New England Division, presided at the public meeting attended by some 200 people. A complete list of those who signed attendance cards is attached.

2) The following is a digest of the major speakers' presentations:

a) Colonel Mason delivered the opening remarks, summarized the background and goals of the study, and discussed the five major elements of work within the New England area as he had done at the Waltham meeting the night before.

b) Mr. Charles F. Kennedy, Director and Chief Engineer, Massachusetts Water Resources Commission, spoke on behalf of Dr. Charles H. W. Foster, Secretary of Environmental Affairs, Commonwealth of Massachusetts. He explained the coordination and interest the State has in the NEWS Study. He also indicated that the Millers River Basin, Alternative No. 2, was the most compatible with the State's water planning philosophy than the other two alternatives. However, other options, he cautioned, although not immediate solutions, should not be ignored. His speech was similar to the one given in Waltham.

c) Mr. Paul E. Pronovost, Study Manager, NEWS, Southeastern New England, made the technical presentation, describing the background of the study team, the problem areas, alternative solutions and our conclusions as he did the night before in Waltham.

d) Mr. Thomas G. Simons, Massachusetts State Representative, Third Franklin District, felt that the state was the key at this point. He knew what the proposal was, but he doesn't know the extent of commitment on the part of the Commonwealth. He felt that the commitment should take the form of protecting the donor area and taking real leadership in minimizing the chances for any future water crisis that would necessitate a diversion of this type.

e) Mr. Henry Waidlick, Selectman, Town of Montague, Massachusetts, stated that he was a landowner along the Millers River and was primarily concerned with water quality. He suggested that we readjust our priorities and direct our attention toward cleaning up our streams and then divert at a later date.

f) Mr. Donald L. Langlois, Selectman, Town of Royalston, Massachusetts, stated that Royalston Board of Selectmen are opposed to the Tully-Millers River Diversion and the Tully Complex Diversion. They felt more can be gained by cleaning up the Millers River and using it as a source of water supply.

g) Mrs. Joan Ashwell, Co-Chairman of the Citizens Participation Group, stated that the group cannot support any of the Millers River Basin alternatives until a number of questions have been answered, primarily by State Agencies.

h) Mrs. Bernard Flood, Public Member, Massachusetts Water Resources Commission, and Chairman, Inter-League Committee for the Connecticut River, believed that the least intrusive on the environment may be Alternative No. 2. However, she raised some questions concerning the effect on the Millers River Basin and on the Connecticut River itself. Also, she felt that the State officials should make their views known so that the citizens will be able to make a decision.

i) Mrs. Rita Barron, Water Resources Chairman, Massachusetts League of Women Voters, stated, as she had at the Waltham public meeting, that the League does not question the needed expansion of the system, but that it should be accompanied by high-level State commitment to responsible management of the water resources of Massachusetts.

j) Mr. Bruce L. Lund, Sanctuary Director, Massachusetts Audubon Society, recommended that the following alternatives be instituted before any of the "crisis" construction begins:

(1) Regulation of consumption -- a community gets a limited amount of water.

(2) Water rate charges -- the larger users should pay more per unit for the more water used.

(3) Water recycling -- especially in industry.

(4) Population zoning -- restrict population and industrial growth in certain areas.

His speech was the same as the one given in Waltham, reflecting the feeling that we should start trying to live within our natural resources.

k) Mrs. Janice Corser, Chairman, Save Our Streams, presented the same speech as Mrs. Celeste McQuillan had the night before at the Waltham public meeting. She stated again that they were opposed to any diversion from the Millers River Basin.

l) Mr. Robert L. Gray, Chairman, Millers River Watershed Council, Inc., repeated his speech of the previous night, explaining that they favored diversion from the Millers River mainstem only or no diversion at all.

m) Mr. Harold W. Willey, Civil Engineer, Construction Division, Metropolitan District Commission, Boston, Massachusetts, presented the same statement for the MDC that Mr. Francis T. Bergin gave at the Waltham public meeting, stating the MDC involvement and relationship to the projects that have been outlined in the NEWS Study.

n) Mr. Terry Blunt, Associate Executive Director, Connecticut River Watershed Council, felt that the availability of water in the Connecticut River Valley had not fully been explored such to deem this water to be diverted surplus. It appears to them that out of valley interests are intending to grab resources from this area without formal acknowledgement of the legitimate owners and without just compensation. He felt that we should start thinking about the long-range comprehensive planning, then talk diversion.

o) Mrs. Jane Van Zandt Brower, Board Member, Connecticut River Ecology Action Corporation, stated that they continue to oppose out-of-basin diversions for reasons previously stated at the 11 January 1972 public meeting. She felt that impact on the environment of the Millers River alternatives was under stated and should be refined.

3) Following the formal presentations, the floor was open to questions. The following is a summary of those questions and answers:

a) Will there be an attempt to raise the dam at Lake Rohunta, adding that drainage area to Quabbin Reservoir?

We have no knowledge of any such proposal.

b) What will the donor area get in return?

For one thing, the MDC has had a tradition of pleasant relations with their donor areas.

4) After all speakers were heard, the meeting was closed at 12:13 a.m.

9. Massachusetts Water Resources Council Meeting

Finally, two public meetings with the Massachusetts Water Resource Council were held in Boston, Massachusetts on 10 April 1972 and 3 August 1972. Both were at the request and held by the Water Resource Council. The Corps stated the progress of the NEWS Study to date and answered any questions. A number of State Agencies, such as the Metropolitan District Commission and the Department of Public Health, were also present and made statements concerning the water supply problems within Massachusetts.

10. Summary of Public Involvement in the Southeastern New England Water Supply Study

The "open planning process" with its constant public contact greatly assisted in the development of the study towards the most advantageous alternatives. However, few comments were made until the best engineering solution was decided upon. Then people began to voice their opinion. The progress meetings, with 50 or so people attending from all walks of life -- engineers, biologists, conservationists, water supply managers, State officials, interested citizens -- provided an excellent sounding board for our ideas. The informational meetings provided the members of the study team with a better understanding of the basin people's attitudes.

It appeared from the two formulation stage public meetings in the Boston Metropolitan area that people were not concerned with their water supply so long as water kept coming out of their tap. Another meeting held some 60 miles from the diversion site, but within the donor basin, was also lightly attended. The reason for poor attendance at these three meetings cannot be blamed on poor publicity. 4500 announcements were sent to every town within the area, watershed councils, League of Women Voters, conservation groups and any known interested citizen. Newspapers in the area carried extensive articles explaining the study

and water supply problems in the area. So, unless people are directly affected by the project, it appeared difficult to involve them in the study.

The formulation stage public meeting at Orange in January 1972 changed the course of the study from the best engineering solution involving diversions from the tributaries to a reinvestigation of the clean-up of the mainstem Millers River. Also, meetings with the Citizens Participation Board reinforced the ideas and feelings voiced at the public meeting.

About six months later, after a number of conferences with State officials and basin representatives, two late stage public meetings to announce our most advantageous plan were held. Again, at the meeting in the Boston area, only a few people attended. But at the basin meeting in Orange, Massachusetts, most of the comments were directed towards State representatives, concerning their role in the study. Of course, a number of people spoke against any diversion at all. Because of this involvement with the public, a more acceptable plan was developed due to a better understanding of the social, economic and political problems involved.

APPENDIX I

EFFECT OF DIVERSION CONTROL FLOW ON PROJECT YIELDS AND COST OF WATER DELIVERED

This appendix explains why the 17,000 cubic feet per second flow on the Connecticut River at Montague City was specified as the control flow. An assessment of the additional yield that would be made available simply by lowering the control flow is presented. However, any change would have to be fully appraised with regard to downstream impacts.

APPENDIX I

EFFECT OF DIVERSION CONTROL FLOW ON PROJECT YIELDS AND COST OF WATER DELIVERED

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APPENDIX I

EFFECT OF DIVERSION CONTROL FLOW ON PROJECT YIELDS AND COST OF WATER DELIVERED

As described in the main report, diversion from the Connecticut River to Quabbin Reservoir via the Northfield Mountain project would be contingent upon the availability of at least 17,000 cfs flow within the River at Montague City. Current Massachusetts State Legislation governing diversion periods from the Connecticut River via Northfield Mountain specifies the adherence to this control flow.

When the initial Massachusetts Legislation regarding this project was passed, the flow restriction was included principally to insure an adequate flow for full generating capacity at the Turners Falls power facilities. When it became necessary to pass supplemental legislation regarding the project, the Metropolitan District Commission held a series of public meetings in 1970. At these state sponsored meetings, a number of citizen and conservation groups expressed the opinion that if this 17,000 cfs control flow was not guaranteed in the supplemental legislation, downstream interests and the environment would be damaged.

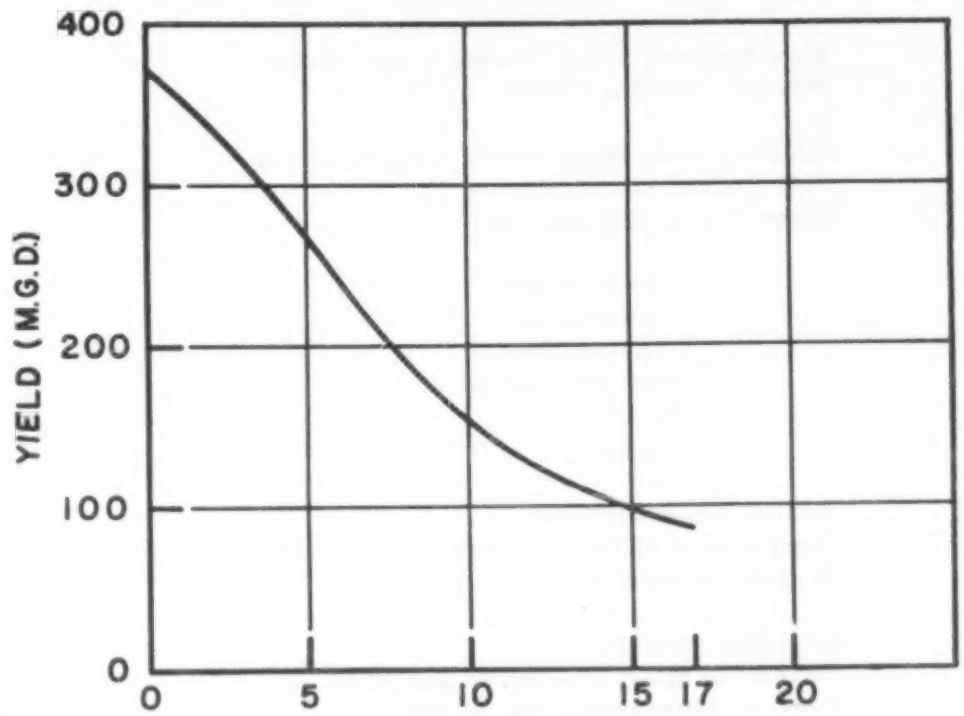
Thus, when the supplemental legislation for the project was passed, the control flow was again included as a provision. Since the date of that latest legislation, the NEWS study has conducted a number of studies regarding impact on the downstream environment. The results of these studies have indicated some reduction of the control flow may be possible without proving deleterious to the environment.

It appears then an opportunity for lowering of the present control flow constraint may be possible in the future. Any change of course would have to be fully appraised with regard to its impact on the environment and socio-economic factors downstream from the diversion intake.

To assess the potential which a lower control flow on the Connecticut River may have, a series of computer runs, using various control flow constraints, were made. The results of these computer applications are shown on Plate No. I-1.

Although lowering the control flow does not change the cost of constructing the project, as illustrated, a definite increase in yield could be realized. For example, if a 10,000 cfs flow rate were adopted in the future, yield available from the project would more than double to about 150 million gallons per day on an average annual basis.

Cost of water delivered from the river would decrease from the $135 per million gallons proposed in this report to about $65 per million gallons. The economics of such a change are apparent.



EFFECT OF CONN. RIVER CONTROL FLOW ON THE YIELD OF THE NORTHFIELD MOUNTAIN PROJECT

PLATE I-1

APPENDIX J — LETTERS OF COMMENT

Comments on the Subject Report were Requested in Letter dated May 1973 from the Following Groups

Federal Agencies

Regional Coordinator
United States Department of the Interior
Boston, Massachusetts 02203

New England River Basins Commission
Boston, Massachusetts 02108

United States Department of Agriculture
Soil Conservation Service
State Conservationist for

Rhode Island
Connecticut
Massachusetts
New Hampshire
Vermont
Maine

Boston Area Director
Department of Housing and Urban Development
Boston, Massachusetts 02114

Regional Director
Bureau of Sport Fisheries and Wildlife
Boston, Massachusetts 02109

Regional Director
National Marine Fisheries Service
Gloucester, Massachusetts 01930

Acting Regional Engineer
Federal Power Commission
New York, New York 10007

District Chief
Water Resources Division
United States Geological Survey
Boston, Massachusetts 02109

Director, Regional Office
Department of Health, Education and Welfare
Boston, Massachusetts 02203

Regional Administrator
Environmental Protection Agency
Region I
Boston, Massachusetts 02203

State Agencies

Director and Chief Engineers
Massachusetts Water Resources Commission
Boston, Massachusetts 02202

Secretary of Environmental Affairs
Commonwealth of Massachusetts
Boston, Massachusetts 02109

Commissioner
Department of Agriculture
State of Connecticut
Hartford, Connecticut 06115

Commissioner
Connecticut Department of Environmental Protection
Hartford, Connecticut 06115

Department of Water Resources
State of Vermont
Montpelier, Vermont 05602

General Manager
State of Rhode Island and Providence Plantations
Water Resources Board
Providence, Rhode Island 02907

Director of Planning
Division of Economic Development
State of New Hampshire
Concord, New Hampshire 03301

Citizen Groups

Citizens Participation Board for the NEWS Study.
Athol, Massachusetts 01331 and 12 members home address.
American Water Works Association
Advisory Committee for the NEWS Study, Washington, D.C.
20004 and 5 members home address.

Comments on the Subject Report Were Received
from the Following Groups

Federal Agencies

Special Assistant to the Secretary, Northeast Region
United States Department of the Interior
Boston, Massachusetts 02203

New England River Basins Commission
Boston, Massachusetts 02108

United States Department of Agriculture
Soil Conservation Service
State Conservationist for:

Connecticut
Massachusetts
New Hampshire
Maine

Boston Area Director
Department of Housing and Urban Development
Boston, Massachusetts 02114

Regional Director
United States Department of the Interior
Bureau of Sport Fisheries and Wildlife
Boston, Massachusetts 02109

Regional Director, Northeast Region
United States Department of Commerce
National Marine Fisheries Service
Gloucester, Massachusetts 01930

Regional Engineer
Federal Power Commission
New York, New York 10007

Federal Agencies
(Cont'd)

Regional Director, Region I
Department of Health, Education and Welfare
Boston, Massachusetts 02203

Division Engineer, Region I
United States Department of Transportation
Federal Highway Administration
Boston, Massachusetts 02203

State Agencies

Chairman, Water Resources Commission
Massachusetts Department of Natural Resources
Boston, Massachusetts 02202

Governor Thomas Meskill
Governor of the State of Connecticut
Hartford, Connecticut 06103

Chairman, Interagency Water Resources
Planning Board
State of Connecticut
Hartford, Connecticut 06115

Acting Commissioner
Agency of Environmental Conservation
Department of Water Resources
State of Vermont
Montpelier, Vermont 05602

Citizen Groups

Citizens Review Committee
Millers River Diversion Plan
Athol, Massachusetts 01331

Massachusetts State Representative
Thomas G. Simons
Boston, Massachusetts 02103

Planning Director
Franklin County Department of Planning
Greenfield, Massachusetts 01301

Mr. Duane R. Leonard
Templeton, Massachusetts 01468

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United States Department of the Interior

OFFICE OF THE SECRETARY
NORTHEAST REGION
JOHN F. KENNEDY FEDERAL BUILDING
ROOM 2003 J & K
BOSTON, MASSACHUSETTS 02203

June 29, 1973

Mr. John W. Leslie, Chief
Engineering Division
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear ~~Mr. Leslie:~~ John

The following are Department of the Interior comments on the technical sections of the two draft reports, "Northfield Mountain Water Supply Project" and "Millers River Basin Water Supply Project," as requested in your letter of May 1, 1973.

In both proposals, the water supply aspects are concerned with ways of diverting water into Quabbin Reservoir to increase the supply for the municipalities served in the area of Metropolitan Boston. The greater part of these reports is a description of the technical and hydrological aspects of the studies. The studies would have been improved if more attention had been devoted to a discussion of the recreation and open space values related to the environmental consequences of the proposals.

Northfield Mountain Project:

With reference to the Northfield Mountain Project, the report does not completely describe the effect of the proposed water supply diversion on the recreational features of the project included in the Exhibit R of the current application to the Federal Power Commission for an operating license. Although the Federal Power Commission has not yet acted on the Exhibit R recommendations,

the pending nature of the license operation deserves special consideration of the possible adverse or beneficial effects on recreation.

Volume I

Page VIII: The cost of and size of proposed ground water developments appear high. This subject was covered in letters dated February 3, 1970 and May 21, 1970 to the North Atlantic Division, Corps of Engineers.

Page VIII: Why not consider ground water in many areas? The U. S. Geological Survey contribution to the SE New England News Study showed 7 areas with a 100 mgd or more potential yield, and 9 other areas with a 50 mgd or more potential yield.

Page 14: Connecticut River drainage includes New England highlands physiographic province in addition to the Conn. Valley lowlands.

Page 19: One and six tenths cfs is more than one mgd not nearly one mgd.

Page 20: Groundwater: The most generous amounts of ground water are in the lower valleys not the upper watershed.

Volumes II and III

Page G-13: 40" of runoff is not 50% of spring runoff. 6" of water per ft. of snow and a minimum of 40" of snow is not believable. Should clarify amount of snowfall and compacted snow.

Page G-16: 15 units for color is generally acceptable; not 25-35 units.
Table G-4 not G-3

Page G-17: Data all mixed up in table G-4.

Page G-19: Paragraph 2. What does the figure 102 mean?

Page G-29: The fecal count shown in table G-9 and 10 does not necessarily indicate untreated sewage. There are other sources. Cows Page G-26.

Page G-30: Alkalinity should not be less than 30 mg/l as $CaCO_3$ Arsenic above EPA limit.

Page G-31: Chromium values reversed.

Page G-38-39: The hypolimnion layer is high in oxygen on p. 38 and low on p. 39.

There appears that iron and manganese will be a problem during the annual turnover of Quabbin Reservoir, therefore treatment of the water prior to its entry to Quabbin will be necessary.

Millers River Basin

In the discussion of Tully Reservoir Diversion (page 143) there is the statement, "As a result, in some Corps reservoirs in New England, some seasonal encroachment for flood control storage has been recommended for other worthwhile uses." Since this may include recreational uses, the report should be expanded to discuss any adverse effects from periodic inundation on recreational facilities.

The 10' diameter conduit used to transfer water from the Tully-Millers River (alternative 2) is stated to have a maximum capacity of 730 cfs (472 mgd) (P.62). During a very dry year (1965) the 17,000 cfs flow at Montague City (plate C-12) was exceeded 6% of the time, therefore 1418 cfs would have to be transmitted through a 730 cfs tunnel. Will there be storage at the intake?

A treatment plant with 928 cfs capacity could possibly be needed to treat Millers River (proper) water for the dry year flow (mentioned above) when quality of water is poor as suspected.

Page 181 - We question the source and accuracy of the figure 5% (4 gallons per day) of domestic water drank.

Page VII - In comparing figures in Table 5-1 with those on pages 72-73, the figures for construction and annual costs do not balance.

Page 175 - The proposed location of the well-field and treatment plant is in the middle of the Miles Standish State Forest. If public land around Quabbin can be used, why not SE Mass?

Page 174 - Smaller wells for lesser yields should be used. This reduces costs and waste.

Inadvertantly, the comments from the Bureau of Sports Fisheries and Wildlife were sent directly to you in a letter dated June 25, 1973.

Sincerely,

Mark Abelson
Special Assistant to the
Secretary

NEW ENGLAND RIVER BASINS COMMISSION
55 COURT STREET · BOSTON, MASSACHUSETTS 02108
PHONE: (617) 223-6244

June 15, 1973

Mr. John William Leslie, Chief
Engineering Division
New England Division
Corps of Engineers
U.S. Dept. of the Army
424 Trapelo Road
Waltham, MA 02154

Dear John:

This letter is in response to your May 1 correspondence which forwarded draft reports titled "Northfield Mountain Water Supply Project" and "Millers River Basin Water Supply Project" for our review and comment.

The findings in these reports are very important to the Commission since they affect each of our major planning programs on the Connecticut River, Long Island Sound and Southeastern New England. The comments herein were prepared by our staff from a perspective provided by work underway or completed on our three studies.

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

The NERBC 1980 Connecticut River Basin Plan has been adopted by the Commission pursuant to the Water Resources Planning Act (PL 89-80) as an increment of a comprehensive, coordinated joint plan (CCJP) for the water and related land resources of New England. The diversion of Connecticut River water by flood skimming into Quabbin Reservoir from the Northfield Mountain pumped storage power project is a component of the adopted plan. The 1980 Basin Plan concludes that the diversion of excess flow at Northfield Mountain is a necessary short term solution. (In addition, both our SENE and LISS studies include an assumption that the Northfield diversion will occur.) However, adoption of this element was conditioned on the following qualifications:

-- continuous environmental assessment with correction of environmental damage

-- prevention of radioactive contamination of diverted waters including a monitoring program

-- provisions for assuring diverted water does not cause the flow to fall below 17,000 cfs at Montague City

The report for the most part deals with the issues underlying these concerns. However, specific provisions for dealing with the issues surrounding operation of the nuclear power plant at Vernon, Vermont should be added. The information provided in Appendix D (referencing Appendix I of the Millers River Basin Water Supply Project) does not contain sufficient information to enable a correlation between plant operation and radioactive contamination of diverted waters.

In addition it occurred to me that the report could be strengthened if the actual recommendation was clearly stated and all the qualifications discussed throughout the various sections of the reports were similarly summarized. For example, statements like the diversion should not occur until secondary wastewater facilities are all in operation upstream of the diversion point, or that MDC should construct the aquaduct and outlet facilities at Quabbin occur in different parts of the report but are not listed together as a set of conditions qualifying the diversion recommendation.

Finally, while we recognize that the detail of the report would not permit the description of a complete monitoring program, it would seem appropriate to include specific criteria for which a monitoring program should be developed. An indication of maximum values for each parameter that would preclude diversion because of quality impact on Quabbin would also be helpful.

MILLERS RIVER BASIN WATER SUPPLY PROJECT

The adopted 1980 Connecticut River Basin Plan recognized the existence of the Tully Diversion proposal but dealt with this proposal and any other diversions (or any increase in the Northfield flood skimming below the 17,000 cfs limit) recommending

that approval of such diversion be conditioned upon:

-- recognition of downstream riparian rights including the right of return of water when needed for water supply or flow augmentation

-- creation of a regional mechanism for allocating water in which downstream states have a voice

-- measurement and evaluation of the potential impact of diverting water before determining what is "excess" flow

-- determination and protection of alternative groundwater sources.

It is suggested that these conditions recommended by NERBC be noted in your report. It is assumed that your forthcoming institutional arrangements study will deal with some of these issues as well as the institutional constraints to the development of local water sources in the MDC area.

Some recognition should also be given to the potential results of the SENE study which might (a) produce recommendations that would alter projected demands for potable supplies; and (b) suggest that additional users not be added to the Quabbin-supplied systems but be served by one or more of the other water supply alternatives your report identified; and (c) consider several alternative mixes of water supply options; your report seems to give the impression that the total future needs must be satisfied exclusively from either diversions or any one of the other alternatives examined.

As you know, at the request of the State of Connecticut, we have made arrangements for a July 10 meeting with representatives of Connecticut and Massachusetts. The primary purpose of this meeting will be to determine the sequence, participants and schedule for performing the tasks necessary to implement the recommendation in the 1980 Basin Plan dealing with regional allocation mechanisms.

We hope that comments of NERBC's staff will be helpful.

Sincerely,

Robert D. Brown
Staff Director

cc: Connecticut - Messers: Lufkin,
Steever
Massachusetts - Messers: Brownell, Foster, & Kennedy

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Mansfield Professional Park, Storrs, Connecticut 06268

June 6, 1973

John Wm. Leslie
Chief, Engineering Division
Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

We appreciate the opportunity to review the technical sections of the draft reports titled NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT AND MILLERS RIVER BASIN WATER SUPPLY PROJECT.

We have no specific comments on the reports submitted, but we wish to assure you of our continuing interest in the progress of all studies of this nature and we should like to be kept informed of the status of such investigations as we have been in the past.

Sincerely,

R. L. Hilliard
acting

Robert L. Hilliard
State Conservationist

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

29 Cottage Street, Amherst, Massachusetts 01002

June 11, 1973

Mr. John William Leslie, Chief
Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Re: Your letter dated May 1, 1973, NEDED-R.

We have reviewed the draft reports titled Northfield Mountain Water Supply Project (2 volumes) and the Millers River Basin Water Supply Project (4 volumes).

The Northfield Mountain report describes the installation of the water supply portion of the Northfield Mountain Pumped Storage Hydroelectric Project. The pumped storage project, now built, has additional storage available for water supply capacity in the upper reservoir.

To provide water supply (72 MGD) for the MDC service area, a ten foot diameter lined tunnel, approximately 10 miles long, will link the pumped storage upper reservoir to Quabbin Reservoir. Water will be diverted to Quabbin only when the Connecticut River flow is over 17,000 cfs at the Turners Falls stream gage. Approximately thirty acres will be used as disposal areas for tunnel muck in conjunction with this project.

The Millers River Water Supply Report described 3 alternative proposals for diversion of water from the Millers Basin into Quabbin Reservoir.

Alternative #1 would take water from the main stem of the Millers River. Alternative #2 would take water from the Millers River and Tully Brook while Alternative #3 would involve additional dams and diversions from Tarbell and Priest Brooks.

Alternative #2 which this report favors over Alternatives 1 and 3, would require tertiary treatment of upstream Millers River sewage sources as would Alternative #1.

Alternative #3 is being dropped from consideration according to this report.

As with the Northfield Mountain diversion, the Tully-Millers diversion does not appear to have a major impact on land use, soils, or sediment and erosion problems.

All disturbed areas and spoil disposal areas should be properly vegetated or otherwise stabilized to prevent erosion.

The reports reflect a considerable effort on the part of your agency to analyze and solve water supply problems.

A major concern with both proposals -- out of basin transfers -- are political and social in nature and are best left to state and local interests to resolve.

I have consulted with the State Conservationist in Vermont and New Hampshire and they have no specific comments.

We appreciate the opportunity to review and comment on these reports.

William H. Carter acting

Dr. Benjamin Isgur
State Conservationist

cc: Craig M. Right, State Conservationist, Vt.
Donald G. Burbank, State Conservationist, N.H.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Federal Building, Durham, New Hampshire 03824

May 4, 1973

Mr. John Leslie, Chief
Engineering Division
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Since both the "Northfield Mountain Water Supply Project" and "Millers River Basin Water Supply Project" fall within Massachusetts, our State Office in Amherst has agreed to provide you with comments on these draft reports.

Sincerely,

D. G. Burbank

Donald G. Burbank
State Conservationist

best copy available

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
USDA Office Building, University of Maine, Orono, Maine 04473

May 28, 1973

Mr. John Wm. Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

RE: NEDED-R

In reference to your letter of May 1, 1973, this will inform you that the Soil Conservation Service in Maine has no comments on the Northfield Mountain Water Supply Project and Millers River Basin Water Supply Project.

Thank you for the opportunity to comment on these draft reports.

Sincerely yours,

D. T. Dinsmore

D. T. Dinsmore
State Conservationist

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
BOSTON AREA OFFICE
BULFINCH BUILDING, 15 NEW CHARDON STREET
BOSTON, MASSACHUSETTS 02114

REGION I
Room 800
John F. Kennedy Federal Building
Boston, Massachusetts 02203

September 19, 1973

IN REPLY REFER TO:
1.1PP

John William Leslie, Chief
Engineering Division
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Subject: Millers Basin - New England Water Supply Study
Review of Draft Report - Environmental Impact
for New England Water Supply

Based on our review of the subject Report, we have determined, based on the Department of Housing and Urban Development's expertise with respect to NEPA, that the above project does not represent any adverse environmental concerns.

It is our recommendation that the above report be referred to the appropriate regional planning agencies for consistency with their comprehensive water studies.

Sincerely,

M. Daniel Richardson, Jr.
Area Director

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
John W. McCormack Post Office and Courthouse
BOSTON, MASSACHUSETTS 02109

JUN 25 1973

Division Engineer
New England Division
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Sir:

The Bureau has reviewed the draft reports titled "Millers River Basin Water Supply Project" (4 Volumes) and "Northfield Mountain Water Supply Project" (3 Volumes) as requested by your letter of May 1, 1973. The following comments are offered for your consideration.

In general these reports treat a complex and difficult subject rather well. However, the conclusions reached are still based on considerable conjecture. As stated in Volume 3 (Millers Project), Appendix I, page 7: "Moreover, the vast majority of complex ecological relationships characteristic of lacustrine and riverine environments are only generally understood if they are understood at all. As yet, our measuring instruments most often yield numerical representatives of ecological systems which are more precise than our understanding of them." This indicates that a good deal of work remains to be done with respect to the environmental impacts of water diversion upon the receiver as well as the donor systems.

Recommendations for further studies, as set forth in Appendix I and Appendix J (Millers Project) and in Appendix G (Northfield Project), are not alluded to in the "Conclusions" section of the Main Reports. We strongly recommend that the necessity for further environmental impact studies be recognized in the Main Reports.

We understand that control flows, as set for the Millers River and tributaries, were set as "best estimates" for planning purposes. This aspect on control flows should be brought out in the Main Report and noted that some leeway exists for adjustment as environmental factors dictate and warrant.

These reports cover ecological considerations of water diversion. They do not, however, include a holistic analysis of the effects of water s supply in light of future power projects, flood management plans, etc. The Bureau of Sport Fisheries and Wildlife feels that the cumulative or synergistic environmental effects of such developments should at least be considered before implementation of major water diversion projects.

Thank you for the opportunity to comment on these reports.

Sincerely yours,

Richard E. Griffith

Regional Director

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northeast Region
Federal Building
14 Elm Street
Gloucester, Massachusetts 01930

May 29, 1973

Division Engineer
New England Division, Corps
of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Sir:

We have reviewed the draft reports entitled "Northfield Mountain Water Supply Project" and "Millers River Basin Water Supply Project," dated March 1973. The draft reports appear to be comprehensive and generally address environmental topics adequately. We would, however, like to offer the following comments:

Northfield Mountain Water Supply Project

Possible Environmental Impacts of Diversion on the Connecticut River - paragraph i), pages 123-124.

It is stated that fishes, phytoplankton, and invertebrate organisms may be entrained and/or trapped at the pumping facility and that "this impact is not occasioned by the fact of the water supply diversion, but rather by the operation of the Northfield project for power production." However, the electric utilities intend to extend the pumping operations an additional 1-1/2 hours per day for water supply purposes and pump about 375 million gallons of water each day that the Connecticut River is in excess of 17,000 cfs at Montague City U.S. Geological Survey gaging station. This expanded pumping operation will increase the potential for entrainment of aquatic organisms, and could be considered in the final report.

Millers River Basin Water Supply Project

Possible Environmental Impacts of Diversion on the Millers River Basin - page 134.

Diversion of water from Millers River to Quabbin Reservoir may affect aquatic life in the vicinity of the river intake. Aquatic organisms of all life stages may be entrained at the pumping facility as a result of the water supply diversion. This should be discussed in the revised report.

59-652 O - 80 - Vol.II - 36

Introduction of undesirable species into Quabbin Reservoir from Millers River is indicated as being possible but not probable, whereas introduction of undesirable species from the Connecticut River had a high probability (Northfield Mountain Water Supply Project, Table 17, page 132). The undesirable species referred to on page 135, Appendix I (Millers River Basin Water Supply Project) include carp, eels, and lampreys. It would seem that the introduction of these species into the Quabbin Reservoir from Millers River also is not only possible but probable. This matter might be given further consideration or clarified in the final report.

We very much appreciate being provided the opportunity of reviewing this draft report. If you believe we can be of further assistance in this matter, please let us know.

Sincerely yours,

Russell T. Norris
Regional Director

FEDERAL POWER COMMISSION
REGIONAL OFFICE
26 Federal Plaza
New York, New York 10007

June 21, 1973

Mr. John Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

We have reviewed the technical section of the draft reports titled "Northfield Mountain Water Supply Project" and "Millers River Basin Water Supply Project". The reports appear to be all inclusive and well documented.

There are, however, a few changes in the upper reservoir statistics which should be refected in the Main Report and in Appendix G. They are as follows:

Main Report - page 51, line 2; change 17,000 acre-feet to 17,240 and 12,750 acre-feet to 12,801 acre-feet.

page 51, Section B-sub-section 1); using the report's data the "additional storage" should read 1,050 (17,000 - 15,950) instead of 1150.

Appendix G - page G-4, first full paragraph; change 15,900 to 16,136; 3,200 to 3,335; and 12,750 to 12,801. These changes would revise the figures in the next paragraph. They would read 48,100,000 cubic feet and 360 million gallons.

We appreciate this opportunity to comment.

Sincerely,

John H. Spellman

John H. Spellman
Regional Engineer

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
REGION I
JOHN F. KENNEDY FEDERAL BUILDING
GOVERNMENT CENTER
BOSTON, MASSACHUSETTS 02203

OFFICE OF
THE REGIONAL DIRECTOR

June 20, 1973

Mr. John Wm. Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

The draft Environmental Impact Statement on the Northfield Mountain Water Supply Project has been reviewed by HEW's Regional Environmental Council.

Our review of the study indicates that many agencies both public and private have participated in this study over a period of perhaps several years.

It appears that adequate considerations have been given by the agencies concerned to the interests of this Department.

It further appears that a comprehensive water supply program for large portions of Massachusetts can be accomplished without an undue adverse effect on the areas where the land use would be changed by collecting and impounding activities. Furthermore the need for potable water in the end may override any other consideration.

It appears also that the improvement of the quality of the water to be eventually impounded into the Quabbin Reservoir by the implementation of this plan is pretty much made mandatory by the "Water Quality" Act of 1972. Therefore those projects recommended by this plan for sewage treatment etc. or perhaps more comprehensive projects will have to be accomplished anyway, regardless of whether this plan is completed or not.

If this plan or portions of it are implemented, we feel that the environmental portions should be updated and made more specific to the area of concern at that time.

We see no other adverse environmental implications resulting from the proposed construction.

Thank you for giving us the opportunity to comment on this statement.

Sincerely yours,

Robert Fulton

Robert Fulton
Regional Director

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
REGION I
JOHN F. KENNEDY FEDERAL BUILDING
GOVERNMENT CENTER
BOSTON, MASSACHUSETTS 02203

June 20, 1973

OFFICE OF
THE REGIONAL DIRECTOR

Mr. John Wm. Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

The draft Environmental Impact Statement on the Millers River Basin Water Supply Project has been reviewed by HEW's Regional Environmental Council.

Our review of the study indicates that many agencies both public and private have participated in this study over a period of perhaps several years.

It appears that adequate considerations have been given by the agencies concerned to the interests of this Department.

It further appears that a comprehensive water supply program for large portions of Massachusetts can be accomplished without an undue adverse effect on the areas where the land use would be changed by collecting and impounding activities. Furthermore, the need for potable water in the end may override any other consideration.

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If this plan or portions of it are implemented, we feel that the environmental portions should be updated and made more specific to the area of concern at that time.

We see no other adverse environmental implications resulting from the proposed construction.

Thank you for giving us the opportunity to comment on this statement.

Sincerely yours,

for Warren M. McGuire
Robert Fulton
Regional Director

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION ONE
612 J.F.K. FEDERAL BUILDING
BOSTON, MASSACHUSETTS 02203

IN REPLY REFER TO:
01-19.4

May 18, 1973

Mr. Meyer S. Slotkin, Acting Chief
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts

Dear Mr. Slotkin:

We have reviewed the technical sections of the draft reports titled "Northfield Mountain Water Supply Project" and "Millers River Basin Water Supply Project" submitted May 2, 1973.

Our only comment concerns Alternative No. 3 - Tully Complex Diversion presented in the Millers River Report. We note that the construction of the Priest Brook Dam would result in the inundation of part of Delano Road and the inundation of Old Turnpike in the town of Royalston. The plans note that these roads are to be abandoned. Although these local roads are not part of the Federal-aid highway system, we would recommend that Old Turnpike Road from Delano Road southerly to Winchendon Road on the westerly side of the reservoir be relocated. This relocation would retain continuity in the widely separated local street system and retain accessibility to a considerable land area. The retention of this system would reduce the impact on the local street pattern, the use of lands adjacent to present property owners and accessibility for fire-fighting equipment, if necessary.

Sincerely yours,

E. Edinsky

for G. R. Turner, Jr.
Division Engineer

The Commonwealth of Massachusetts
Department of Natural Resources
Leverett Saltonstall Building
100 Cambridge Street, Boston 02202

FRANCIS W. SARGENT
GOVERNOR

ARTHUR W. BROWNELL
COMMISSIONER

August 13, 1973

John H. Mason
Colonel, Corps of Engineers
Division Engineer
Department of the Army
New England Division,
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Mason:

Over the past three months the Massachusetts Water Resources Commission has examined the six-volume Northfield Mountain and Millers River Basin Water Supply Project reports, generated by the Northeast Water Supply Study. It is my pleasure to report concurrence on the following position statement regarding the study reports:

The Massachusetts Water Resources Commission has considered the draft Northeastern United States Water Supply Project: Northfield Mountain-Millers River Basin Projects submitted to us for review and comment. We find that your evaluation of the study area's current and future water supply needs is justified, realizing, of course, that trends may change, altering even the most carefully formulated projections. We also find that you have identified the major water supply sources which might reasonably be foreseen to be available within the time frames to be served. Environmental impacts have been adequately identified and evaluated within the constraints imposed by the imperfect knowledge of the more subtle ecological effects which might occur. We are pleased to accept the study and array of alternatives as a major water planning contribution, and a valued input to a state water plan.

We recommend that further detailed planning and implementation proceed, particularly with the Millers River Alternate 2 (two) proposal. Like the Northfield Project, the Millers River Basin proposal would involve diversions only during high flow periods. The General Court of Massachusetts has already authorized the Metropolitan District Commission to proceed with the Northfield project. The Tully-Millers Diversion Plan combines recreational use and a maximum level of pollution abatement with the water supply function. Diversion from the East Branch of the Tully River will afford a reasonable period of time to partially use the proposed tunnel from the Millers basin to Quabbin Reservoir -- during which time

the best elements of modern technology will be brought to bear to improve the water quality of the Millers River mainstem preparatory to its introduction to Quabbin. Diversion from the Tully will not delay or otherwise affect the planned improvements in the quality of Millers River water which will go forward pursuant to a fixed schedule. It is further conceivable that the needed improvements in the water quality of the Millers River might be achieved prior to the time that construction could be completed on the Tully-Millers scheme (Alternate 2). In that event, only that portion of the diversion works running from the Millers River, itself, to Quabbin, need be constructed, the utilization of the Tully River being rendered unnecessary.

The Commission is aware that full consideration is owed the donor area, and we commit ourselves to foster the legitimate local interests which have been expressed with both candor and dignity. We support the diversion from the Millers Basin as a part of a broader river basin plan which would be authorized concurrently with any future state enabling legislation regarding the diversion of flows from the Millers River Basin. The planning program would encompass, but not be limited to the following elements:

-- the possible creation of a permanent advisory river basin entity involving citizens and agencies in formulating plans and recommending management measures

-- a detailed mathematical modeling and water quality monitoring program to yield information needed to insure flow maintenance and to achieve a very high degree of pollution abatement -- at least to the level necessary for introduction of the Millers mainstem into Quabbin

-- the implementation of the state scenic rivers program on the mainstem and suitable tributaries

-- acquisition of additional land to complement existing open space lands now owned in the watershed for fisheries and wildlife, forestry and park purposes

-- a detailed delineation of areas which should be placed under a program of floodplain management

-- a detailed compilation of areas favorable for ground water development

-- s study to see if the utilization of state powers to preserve reservoir sites is needed for the protection of the donor area's future water supply options

-- a plan to provide access to high value outdoor recreation areas, especially those areas enhanced by the water pollution abatement program.

In summary, we foresee a state role in formulating a comprehensive plan for the Millers River Basin in which diversion, though a basic part, is but one aspect of water resource management to be implemented.

The Commission also acknowledges that its rightful role in the donee area is not limited to that of providing a water supply. Other water resource management functions here will include, but not be limited to, the following:

--continue studies to insure that opportunities to obtain yields from local sources, consistent with sound resource management, are fully utilized.

-- provide an educational program to emphasize the finite nature of our water resources, to discourage waste, and to coordinate this plan with water districts and departments

-- Make a continuing study of changing technologies which may make the use of saline and wastewater a viable alternative

-- obtain more detailed information on how water is currently distributed and used, to see if measures such as changes in pricing, dual supplies, industrial re-use, etc. can be feasible means of conserving high quality water, thus lessening the demand on Quabbin Reservoir.

Much of the foregoing can be accomplished with present state, regional and federal programs, though changes in priorities and additional funding would in some degree be required. However, like the NEWS study itself, the diversion projects are endeavors of major magnitude. Just as this very worthwhile study could only have been accomplished by the Congressional authorization of Federal participation in 1965, detailed planning and implementation can best be accomplished by the continuation of the effective State-Federal partnership achieved during the course of the study. We respectfully suggest that this report go forward to Congress with a request for continued Federal participation in a program of detailed planning and implementation.

The Massachusetts Water Resources Commission recognizes, and has identified in the foregoing, a strong state role in planning an overall basin program which is economically equitable, environmentally sensitive, and socially acceptable. Citizen participation has rightfully made us aware of our duty to maintain the basic integrity of river eco-systems and the economic self-interest of donor areas.

The Massachusetts Water Resources Commission understands that favorable Congressional action may establish funds for completing final engineering plans and defining institutional and cost-sharing arrangements. It is our further current belief that positive results of such a legislative program would be the actual construction of a water diversion tunnel from the Millers River Basin to Quabbin Reservoir by 1980.

Based on the foregoing assumptions, the Commission endorses the following implementation schedule:

By July 1, 1977, all point sources on the Millers River and its tributaries will be receiving the best practicable treatment available. This program will be administered by the Massachusetts Division of Water Pollution Control.

By 1979, advanced techniques of water treatment, if needed to produce water in the Millers River mainstem suitable for diversion to Quabbin Reservoir, will be developed and in operation under a Congressionally authorized cooperative federal-state program.

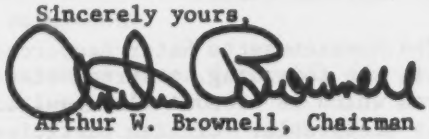
During the period from the completion of the required advanced waste treatment units in 1979, and prior to the completion of tunnel construction and diversion works, special studies of the actual quality of the restored Millers River will be conducted under the supervision of the Massachusetts Department of Public Health. Before actual diversion of the water from the Millers River mainstem is begun, the Department of Public Health shall be satisfied that adequate health safeguards are operative.

A strong input at the state level to achieve a comprehensive and equitable plan for the basin, coupled with the proven engineering ability of the Department of the Army's Corps of Engineers, will provide a practical means to complete two major vital elements to meet the long range water supply needs of the Northeastern United States. We support and recommend that additional Congressional authorization and funding be sought for the planning and implementation of the Northfield Mountain and Millers River Basin diversions.

Voted at the Regular meeting of the Massachusetts Water Resources Commission, August 13, 1973.

We appreciate the extended review period afforded us. During the past eight weeks, we have received additional inputs from Commission members and individuals. You may utilize this statement for appropriate purposes in connection with submissions to Congress regarding later phases of these important project proposals.

Sincerely yours,



Arthur W. Brownell, Chairman
Water Resources Commission

AWB/ehc/m

The Commonwealth of Massachusetts
Department of Natural Resources
State Office Building, Government Center
100 Cambridge Street, Boston 02202

June 11, 1973

Colonel John Mason
Department of the U.S. Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Mason:

First, I wish to compliment the New England Division of the Corps of Engineers on its contribution to the Northeast United States Water Supply Study. We received the six (6) draft volumes and forwarded them to Commission Members for review on May 4 to May 8, 1973. With incomplete returns in hand, we distributed a tentative Water Resources Commission position draft to its members at the regular meeting on June 11, 1973.

The Commission was not in a position to act, but rather accepted the draft statement for study. Additional member inputs will be reviewed and included in a second draft position to be considered at the meeting of July 9, 1973. It is unlikely, therefore, that the final state position will be formalized until eight weeks hence.

We, therefore, respectfully request that eight weeks be added to the review period which was originally planned to terminate on July 15, 1973. We wish to acknowledge requests from citizens' groups for this extension, but hasten to add that their desires were not alone the decisive issue in our request for additional time. We are most desirous of providing a thoughtful and productive review of this extremely important study.

Sincerely yours,

Arthur W. Brownell, Chairman

Citizens Review Committee
Millers River Diversion Project

273 Bearsden Road
Athol, MA 01331

June 12, 1973

Col. John H. Mason
U. S. Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Sir,

On Monday, June 11, 1973, the Citizens Review Committee were represented at the regular meeting of the Massachusetts Water Resource Commission.

At that meeting we requested that the Commission ask for a sixty (60) day extension in the deadline set for our cooperative reply to the Millers River Diversion Report (Draft). A motion, to this effect, was made and received a unanimous vote in the affirmative. This would extend the deadline to August 15, 1973.

We plan to use this additional time to meet with the various state agencies involved and receive from them a definate and firm commitment regarding their agencies necessary involvement. Also this will give the committee sufficient time to allow a hydrologist, whom we have retained, to study the report and make recommendations to our committee. Finally, it will allow us to study, draft, and finalize a cooperative reply to your complete report.

Thanking you for your consideration of our views, I remain,

Yours Truly,

Robert L. Gray

Robert L. Gray, Chairman
Citizens Review Committee
Millers River Diversion Project

STATE OF CONNECTICUT

DEPARTMENT OF FINANCE & CONTROL
OFFICE OF STATE PLANNING
340 CAPITOL AVENUE - HARTFORD, CONNECTICUT 06106

June 19, 1973

Mr. John W. Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

By letter dated May 14, 1973 to Colonel Richard J. Hess, copy attached, I have been appointed by Governor Meskill as the Coordinator for the NEWS Study for the State of Connecticut. I am writing to you concerning your request for comments by state agencies on the draft reports titled, "Northfield Mountain Water Supply Project" and "Millers River Basin Supply Project" by June 15, 1973. Several state agencies are presently reviewing these reports and I have advised them that any commentary should be directed to this office so that a coordinated response may be forwarded. It will be impossible to have this forwarded to you by the June 15 date but it will be sent as soon thereafter as possible.

I would appreciate being advised of the anticipated timetable of any other matters involving coordination with state agencies which you may have scheduled for the near future.

Sincerely,

Harold I. Ames
Assistant Director

HIA:SA:hab

Attachment

STATE OF CONNECTICUT

DEPARTMENT OF FINANCE & CONTROL
OFFICE OF STATE PLANNING
340 CAPITOL AVENUE - HARTFORD, CONNECTICUT 06106

June 22, 1973

Mr. John W. Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Enclosed are several staff memos providing preliminary comments from Connecticut State Agencies (Department of Environmental Protection and the Office of State Planning, Department of Finance and Control) on the draft reports entitled, "Northfield Mountain Water Supply Project" and "Millers River Basin Supply Project." Due to vacation schedules and the desire to respond as soon as possible, I am forwarding these comments to you in this form. The Connecticut Department of Environmental Protection is preparing additional comments which will be forwarded next week and should be considered a part of this submittal.

These are preliminary comments by technical staffs of the state agencies which identify several areas of concern with these projects as they relate to the interests of the State of Connecticut. It is my understanding that in the near future your office will be working on the preparation of draft EIS for these projects and there will be opportunity for an official statement of State of Connecticut position and concerns to be included therein. In the interest of developing that with the best possible information, I would like to suggest that it would be helpful if there could be arranged a face-to-face meeting of the several state people involved with key personnel of the Corps of Engineers who are most directly involved and most knowledgeable on these projects particularly as related to the concerns raised in the attached review memos.

One additional broad area of concern which I would like to raise on these reports is the need for more information and consideration of alternatives on water demand as reflected by projections of population, economic activi-

ties, consumption rates, etc. I would ask that this be considered another subject for discussion in the meeting suggested above. I would appreciate hearing from you concerning such a meeting and will be happy to coordinate arrangements for same at this end. We greatly appreciate this opportunity for review of these study reports and for submitting the concerns of the State of Connecticut. I look forward to hearing from you re: the suggested meeting for closer coordination.

Sincerely,

Harold I. Ames
Assistant Director

HIA:sm

cc: R. Anderson
M. Gravitz
D. Lufkin
G. Oberts
P. Reilly
R. Woodhull

59-652 O - 80 - Vol.II - 37

Peter Reilly — Policy, Planning and Research — 4 June 1973

Gary L. Oberts — Water and Related Resources

Environmental Analyst

Northeastern U.S. Water Supply Study review for comments

RECEIVED
JUN 13
Conn. Office of State Planning
Dept. of Finance & Control

I) Volume I, Main Report Millers River Basin

Figures for year 2020 require 550 mgd; 1990 figures require 125 mgd; this increase of about 100% per decade is scarey and in my opinion poses a definite threat to Connecticut; diversion out of a watershed throws off the hydrologic cycle and the resultant unbalance may cause such ill effects as well dry-ups, loss of adequate water supply, decrease in water quality, etc.

High flow withdrawal threatens to cut off recharge of aquifers located along the floodplain of the Connecticut River as referred to in the "Role of Connecticut River Flood Flows in Recharging Ground-Water Formations" by O. C. Farquanar, a draft report submitted to the Directore of the Water Resources Research Center, University of Massachusetts, Amherst, Massachusetts; with the proposed plans only a small amount of the flood flow will be withdrawn, but the cumulative result which may follow the precedent would have a marked effect on Connecticut; also many biota need spring freshet to trigger their reproductive urges and upstream migration.

I would like to see some sort of hydrologic study done to show why the minimum skimming figure of 17,000 c.f.s. (p. xxiv) was chosen; I agree with the Commissioner's comments in his letter to Mr. Ledie on the subject.

I am totally against any form of weather modification as described on p. xxxv.

They seem only to care about the best cost-benefit they can get and basically ignore downstream implications and the precedent they are setting.

Although they only propose to take 1%, a minimal amount, the precedent will be set for future diversions of Connecticut River water upstream. Also the 1% will occur within a timespan of only two or three critical months when flushing and floodplain recharge are essential to the riverine ecosystem and associated physical phenomena.

II) Volume I, Main Report, Northfield Mtn.

Again, the diversion now presents no real threat to the total flow of the Connecticut River, but future projects may also decide to "skim" and thus limit the flow of freshets entering Connecticut to a further extent; freshet flow is needed to flush the river and to recharge the floodway, so freshet control is not an environmentally sound practise; the report pays very little attention to this fact.

III) Appendices

The quantitative data presented in the various appendices do a very good job of supporting the proposed diversions; they've succeeded in showing that this particular proposal is minimal with support to the State of Connecticut, but they've totally ignored the fact that the precedent being set could be disastrous in the future.

My overall opinion on the report is that it looks only to the Boston area and feels other areas, specifically Connecticut, are unimportant; this is reflected in their various economic statements in which they ignore any additional costs that their diversion may place upon Connecticut. I think the Commissioner's comments of December 21, 1972 are very good and accurate; I concur with him on all of those particular statements.

Gary L Oberts
Environmental Analyst

GLO:ljg

... EXECUTIVE DEPARTMENT

... 273

Use carbon if you really need a copy. If convenient, ignore faint lines.

TO Roy B. Anderson	AGENCY DEP	DATE 6/4/73
FROM Michael Gravitz	AGENCY DEP	TELEPHONE
SUBJECT NORTHFIELD MOUNTAIN AND MILLERS RIVER BASIN WATER SUPPLY DRAFT PRELIMINARY ENVIRONMENTAL IMPACT STATEMENT		

I have two major areas of criticism of the Army Corps proposals for diversions from Northfield Mountain and Miller's River Basin: water quality and benefit/cost analysis.

It is proposed to divert some of the Connecticut River's flow at the Northfield Mountain pumped storage hydroelectric power facility "during high flow periods, principally during spring run-off periods". It is not exactly clear whether the corps will limit the diversions to a period they call spring freshet or whether they will pump extra water to Quabbin Reservoir via Northfield Mountain at other times of high flows during the year. The definition of reshet itself seems to be artificial. It is keyed to a river flow at which there is no tidal upstream flow at Bockin rock in Middletown. The flow that is hydrologically necessary to maintain this condition, assuming no more downstream diversions or storage ie Enfield Dam, is strangely similar to 17.000 cfs flow at Montague City, Mass. Also this "magic" figure of a minimum 17,000 cfs flow at Montague was a directive from the Mass. legislature and seems to be necessary for some downstream dams. Thus this figure of a minimum flow of 17,000 cfs seems a bit arbitary and oriented more towards industrial-power generating needs than river ecosystems. Thus one reason that this figure is used as a minimum is because it works in terms of downstream needs, salinity and temperature.

Hydrologic and Water Quality Questions, Considerations

1. What functions does the"freshet" perform for the river's morphology and ecosystem?

2. Of these functions, which ones may be altered by the diversion?

3. The diversion could change the river's morphology page 89 Preliminary EIS.

Water Quality

1. The E.I.S. says that increased concentrations of nutrients due to diversions would be insignificant, but it does not discuss the possible increased concentration of conservative materials like metals, etc. or nonconservative ones like BOD or D.O.

2. What could be some of the effects on water quality from the detention of water in the Northfield Mountain reservoir?

3. In discussing impacts on river quality, the only detailed consideration is given to salinity and temperature changes in what they call the Connecticut River estuary (Enfield Dam to Old Saybrook). However, there are many other physical-chemical and biological parameters that could change because of the diversion.

4. One irreversible impact or use of the river would be its decreased capacity to accept thermal wastes and still maintain water quality standards due to the predicted rise in the river's temperature because of the diversion. Here to is a hidden cost of the proposed diversion which Connecticut would have to bear and which the corps analysis of cost does not seem to include.

5. The EIS insists that the salinity interface would not change as long as a control flow of 17,000 CFS were maintained at Montague. However, they have not modeled the lower estuary (Haddam to Long Island Sound) for salinity in order to evaluate in detail the effects that proposed changes in flow regimen might have. They use a set of 1966 salinity data to prove there point, but its logic is confusing. They show that at a discharge of 17,798 cfs belo Thompsonville, a salinity of one part per thousand lies no farther up than river mile 2.4. But this has no bearing on their proposed diversion. What is important to know is that given the discharges of the Enfield Dam what effects would the diversion have on lessening this volume and the resulting salinity changes, if any.

It seems probable that there would be a shift in salinity gradients due to this diversion. The Essex Marine Laboratory report done for the corps on temperature and salinity effects of the diversion states quite clearly: "No biological data is available regarding the distributi and relative abundance of fish from mile 6.5 to the Connecticut River mouth. As apparent from the station mentioned above, this area is a vast nursery ground for many marine species. It is <u>impossible to judge</u> the effects of the further intrusion of salt water into the estuary due to diversion without at least some limited studies of the life stages of fishes in this lower part of the estuary.". Page 85 Vol.4 Draft Millers River Basin Water Supply Project.

The question of salinity changes definitely needs more investigation.

6. Why do they have to pump 580 cfs = 375 mgd from the river in order to supply only 110 cfs = 72 mgd to Quabbin? This ratio of increased pumped water: yield to Quabbin is approximately 5:1.

7. There is no real data on fish and benthic entrainment due to increased pumping, especially for entrainment of anadramous fish which will some day be able to go over Turner's Falls.

<u>Criticisms, Questions on Benefits/Cost Analyses</u>

1. The Corps estimated cost of 43 million dollars for the Northfield diversion does not include any of the costs of building the pumped storage facility itself, so that this estimate may not reflect all real costs.

2. There is generally a very weak analysis of alternatives to the proposa besides those in the Millers River Basin. The redevelopment of the Sudbury reservoirs, Swift and Ware river diversions, or groundwater do not receive very much attention. Also the possibility of meeting future increases in demand for water by the development of local supply systems rather than massively increasing the capacity of the regional MDC system has not been effectively dealt with.

3. The impact statement states that there are probable "safe yield" groundwater reserves of 300 mgd in Plymouth County, Mass. This is in an area immediately southeast of Boston; and the quantity of good quality groundwater that is indefinitely available "exceeds the required quantity established as a goal of this study (the E.I.S.)". The Corps estimated the "first cost" or capital cost of developing this groundwater as $1.2 million/mgd versus $540,000/mgd for the Connecticut River diversion. However, the cost of the Conn. River diversion seems to ignore the basic cost of the Northfield Mountain facility itself. The operating costs of the groundwater system are estimated at twice the cost per 1,000 gals. of the diversion scheme. However, there is no detailed cost breakdown of this in the report, and the cheaper cost of the diverted water may reflect the artificial low cost of the off-peak Northfield Mountain hydroelectric power used. The E.I.S. criticizes the use of groundwater because of its high use of electricity for pumping, but the Northfield Mountain diversion also would use large quantities of electricity.

4. The E.I.S. estimates the cost of a "no action" decision on the diversi at $83 million through 1990 versus a cost to build it of $43 million (cheapened cost).

5. The benefits of this project will last only until 1990. With a projected date of completion of the diversion in 1976, this gives a benefit time frame of only 14 years at most. This seems to be a very short term benefit from a potentially environmentally destructive project.

6. The analysis of the "no action" decision on the diversions does not consider a slower use of Quabbin reservoir and a development of other regional or local supply alternatives. They also use all 3 alternativ at once in an analysis of the "no action" decision. This in effect makes the "no action" alternative look more drastic in its consequence than if "no action" had been considered separately for all 3 alternati

7. An important cost which the state of Connecticut may have to bear is the increased cost due to increasing concentrations of pollutants in the river.

8. Perhaps the most important criticism to be made of this project is recognized in a letter from Dan Lufkin to John Leslie, Chief Engineer, Division of U.S. Army Corps of Engineers dated December 21, 1972. This diversion project sets a "precedent for future diversion of the Connecticut River by upstream states. Connecticut has no control or input into the decision about how many diversions are allowable and how much water may be diverted from the Connecticut River basin to the possible detriment of the river's quality as it flows through Connecticut. It seems very probable that the 100 cfs which is to be diverted daily at Northfield Mountain is only a beginning at this site, because even with the Tully diversions added to the

proposed Connecticut River diversion the volume of water in Quabbin will steadily decline after 1989. Thus there will be pressure to divert more and more of the Connecticut's water at this site. This brief scenario does not even take into account other possible demands on the Connecticut River at other diversion sites. Clearly there ought to be a more rational and equitable method for apportioning the resources of the Connecticut River than by the decisions of individual state legislatures in the basin. Perhaps this E.I.S. ought to deal with the incremental effects that possible future diversions would have on the river if this one at Northfield Mountain is allowed to set a precedent.

MG/am

Send In A Suggestion — Earn A Cash Award

INTERDEPARTMENT MESSAGE
STO-201 6-72

SAVE TIME: *Handwritten messages are acceptable.*
Use carbon if you really need a copy. If typewritten, ignore faint lines.

TO	AGENCY	DATE
Harold Ames	OSP	6/20/73
FROM	AGENCY	TELEPHONE
Sidney Albertsen	OSP	5614

SUBJECT
Review of Draft Reports, "Millers River Basin Water Supply Project and Northfield Mountain Water Supply Project"

I have reviewed the above reports and have the following comments to make. Of course the primary concern to Connecticut is the effect the proposed diversions would have on the Connecticut River. There are three main areas on which I would like to comment: the use of polluted sources of water, groundwater in Plymouth County, and the cost estimates.

I question the use of the Connecticut River and the Millers River for potable purposes. In the reports one of the alternatives, which was reviewed and not accepted as being feasible, was that of the reuse of wastewater for water supply purposes. The report states, "Health officials feel that many questions remain unanswered which must be fully investigated if renovated waste water is to be considered for drinking water purposes." The reports then go on to say, "Use common sense. Renovated wastewater should not be used for the ultimate personal use--as a drinking-water supply--until there is no other practical choice; and then, hopefully, the minimum research will have been completed and the use will be carefully operated and controlled....use of renovated wastewater as a regular domestic supply, however, requires full results of proposed research. Until such research is completed, wastewater reuse as a municipal water supply is not a viable alternative to meet short-range supply needs....The use of such waste water effluent, regardless of the degree of waste water treatment, as a source of supply for municipal systems is not sanctioned at this time. Echoing the position of the Division of Water Supply, Environmental Protection Agency, State and local health officials and professional water supply engineers, any application of reused water as a municipal supply would require a considerable amount of research on associated potential health hazards. Since, in many regions, less than desirable sources may be needed in the future, it is imperative that such research be accelerated." From the information available to me I wholeheartedly endorse the above stand. In addition, I feel that the same arguments can be applied to not using polluted sources of supply for potable purposes (Connecticut River and Millers River in this case). These streams would basically contain the same contaminants as wastewater. Both can be purified to the same extent possible. The only difference would be the greater cost of cleaning up wastewater for use for potable purposes. In Volume III, Appendix I, this draft report does go on to say that "It is to be noted that even the best of the conventional treatment practices may produce an effluent which may still contain infectious viruses...as Dr. Plotkin suggested, even after the viral concentration has been reduced 99.9999%, we have a level of ingestion of virus that could be responsible for a proportion of the

endemic viral diseases in communities consuming highly treated waters." However, in the summary to the section on viruses after citing many negative aspects of using polluted sources the reports then come to the opposite conclusion. It is stated that "...practical experience with public water supplies suggests that much of the concern expressed over the dangers of viral agents in water supplies is academic. For example, the Massachusetts Department of Public Health has carefully monitored the public health effects of the consumption of water taken from the Merrimack River by the cities of Lawrence and Lowell. No detriment to public health has ever been noted as a result of this consumption, even though we must assume, on scientific grounds discussed above, that viral agents are present in the Merrimack River. It is therefore, a mistake to presume that scientific concerns are always real concerns. It would also be a mistake to disregard completely such concerns." I feel that such a conclusion is only tenuous at best. In an article entitled, Drinking Water Policy and Practice in Connecticut, Mr. Richard Woodhull, Chief of the Water Supplies Section of the Connecticut State Department of Health states certain things which seem to contradict the conclusions drawn in these reports and raise questions about the feasibility of utilizing polluted sources for potable water supply purposes. Mr. Woodhull in this article says that, "Research reinforced by case history has shown that virus particles are also carried by drinking water. This was demonstrated by widespread dissemination of infectious hepatitis in New Delhi in 1955 and among members of the Holy Cross football team in Worcester more recently. Viruses have been implicated in certain forms of conjunctivitis, meningitis, and cancer, and some feel they may be involved in some cases of appendicitis, heart disease and spontaneous abortion. ...In 1970 the Federal Environmental Protection Agency released a report which stated: '...we are not sure today whether or not current water treatment processes are definitely capable of eliminating all harmful viral pollutants from all water supplies. Also we wonder whether or not the treatment will provide the public with sufficient margin of safety to cope with the occasional occurrence of the very unfavorable conditions. These conditions, for instance, may include severe epidemics of human enteric virus disease, unfavorable hydrographical conditions, drought, cold weather and many others..there is highly circumstantial evidence to suggest that the high annual incidence of infectious hepatitis may be partially attributable to a widespread and chronic water pollution with low levels of this virus.' " Mr. Woodhull's article goes on to say that, "In March of 1972, the Environmental Protection Agency reported at a Washington hearing before the Senate Subcommittee of the Environment that disease producing viruses had been found in the tap water at Billerica and at Lawrence in Massachusetts. Both cities use polluted water sources, Billerica drawing from the Concord River and Lawrence taking its water from the Merrimack River. Both cities have complete water treatment facilities, including filtration and chlorination. Of 32 samples of drinking water tested from each system, viruses were present in two of Lawrence's and four of Billerica's." This discussion contradicts the conclusions drawn in these reports on the safety of viruses. At some time in the future a breakthrough may occur and it may be feasible to safely use polluted sources of water for potable purposes. Therefore, the use of both the Connecticut River by Massachusetts and Connecticut and other polluted bodies of water for potable purposes should not be precluded in the future. However, I do agree with the conclusions of these reports in one respect, which is that the use of polluted sources, such as the Millers River and the Connecticut River, is preferable

to having a shortage of potable water. I am not yet convinced that there are not other sources which are available and at the same time of better quality. Specifically, I am referring to the groundwater which exists in Plymouth County and on Cape Cod.

The reports state that the groundwater on Cape Cod will be needed to serve the expected population of that area. I would like to see figures on the amount of water which is available and what the projected population is expected to be. Also, in Volume 1, the Main Report on the Millers River Project on page 149 it states that in building tunnels for this diversion the possibility of disrupting local groundwater supplies is low. I ask what are these groundwater supplies which exist in this area? Do they have any potential for major withdrawals of water for potable purposes for the Boston area? In Volume 1, Main Report of the Northfield Mountain Water Report it also says that "The total quantity of groundwater available from the(Connecticut) basin is perhaps more than 1 billion gallons per day. The more generous amounts are located in the upper watershed where demands are lightest." Again, I would ask what portion, if any, of this 1 billion gallons per day could be available for use in the Boston area? These reports state that the groundwater study was based upon analysis and interpretation of available data and did not include any new exploratory work. With such a great demand for water supply envisioned for the future I believe it might be appropriate if more detailed groundwater analyses and studies are initiated. I think that the method of comparison is inaccurate. The costs and amount of acreage needed for groundwater are duplicated by comparing groundwater separately against both the Northfield Mountain Project and the Millers River Project. A correct comparison would be of the costs of the groundwater compared to the total costs of both of these water supply projects.

The two main objections to the use of the groundwater are those of cost and socio-economic impacts. I would like information as to the basis that 1,000 to 1,500 acres of land would be necessary for the use of the groundwater. Would not it be possible to use public lands, such as state parks, for the location of the wells? I do not understand how the building of aqueduct systems and other necessary facilities for the use of groundwater can cause what would be considered a great disruption and a serious impact on the environment. What is the basis for the statement that the annual costs of groundwater development would be about 25¢ per 1,000 gallons produced? I would like to see a breakdown of the costs that would be involved in arriving at this figure. It is requested that the Corps recheck their cost figures for the Northfield Mountain Project. On page XXXViii of Volume 1, Main Report on the Millers River Project it states that the costs for the project would be $462,000 per mgd capacity. On page D-16 of Volume II, Appendix A-H, it says that the first costs of this project would be $33,147,000. There appears to be a discrepancy of about $2,000,000 between these two figures. The $462,000 per mgd capacity, when computed by the 68 mgd average annual yield for Millers comes out to $31,416,000. Basically, a source, such as the 300 MGD groundwater supply available in Plymouth County, should be given greater consideration than I feel has been given in these reports.

It is desirable to take into consideration the cost of a project. However, there are other factors which have to be weighed in the selection of recommendations for water supply. The least costly alternative is not always the best one. In my opinion it is not worth the saving to utilize polluted sources of water (Northfield Mountain Project and Millers River) for potable drinking water purposes. The Millers River Project and the Northfield Mountain Project combined would satisfy a future need of 141 MGD. Is the cost for developing the groundwater based on the development of the total figure of 300 MGD, which is potentially available or is it based upon the cost of developing the groundwater to satisfy the expected demand of 141 MGD? I am also not yet convinced that the costs for groundwater would be as high as is maintained in this report. There should be a further investigation of the feasibility of using groundwater to satisfy the water supply needs of the greater Boston area. The use of polluted sources should be considered as a last resort. I am not convinced that this is the situation which now exists.

One last item should be mentioned. There is no mention in the reports of the consideration or the feasibility of building surface impoundments for water supply purposes. Are there no sites in Massachusetts which can be impounded for potable purposes? There may be many problems including higher costs, for the construction of surface reservoirs, however, I feel that this alternative should be investigated and the results of the investigation reported.

SA:hab

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

STATE OFFICE BUILDING HARTFORD, CONNECTICUT 06115

December 21, 1972

Mr. John Wm. Leslie
Chief, Engineering Division
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Subject: Preliminary Draft Environmental Statement of the Northfield Mountain Water Supply Project on the Miller's River Basin Water Supply Project

Introduction

The Department of Environmental Protection (DEP) is gravely concerned about diversions from the Connecticut River outside of the river basin. DEP wishes to express its concern on this Northfield Mountain/Miller's River Basin Water Supply Projects, as the State of Connecticut did in 1931 with the diversion of the Swift River. We believe no State Legislature should have the sole right to determine the extent of diversions from a river which flows through other states downstream. For this reason DEP believes that a regional group should be empowered to (1) determine what is the maximum amount of water that can be diverted from the Connecticut River Basin based on the requirements of the river, the dependent eco systems and the people who live along it, and (2) allocate that amount of "divertable" water amongst states by criteria acceptable to all parties involved. DEP feels that the existing New England River Basins Commission can serve this function.

DEP's concerns about furthering the precedent of upstream diversions can be seen most clearly on Figure 1, P. 63. Quabbin and the Swift diversion started in the 1930's and according to Figure 1, it will run dry around 1984 or a period of about 50 years, a half-century. However with the proposed Connecticut diversion only, the end of Quabbin is only prolonged by about eleven years, a decade. Even with the most optimistic figures including the Tully diversions, the fate is prolonged only two decades. Clearly these are only short-term solutions. DEP's concern is that this action is a precedent for future diversions out of the Connecticut River Basin for which no impacts or controls have been discussed or dealt with, and no ongoing mechanism has been set up to handle these questions amongst states.
Therefore DEP requests that this action be stopped until a regional body such as the New England River Basins Commission can meet and develop solutions equitable to all parties involved.

In addition DEP would like to comment on the Preliminary Draft EIS by section. Our policy on the review was to consider only the points involving the State of Connecticut as there are ample reviewers from other States.

Section 1. This section is inadequate. The CEQ guidelines require that the EIS consider the overall cumulative impacts including future actions planned. DEP feels a clear statement should be made of how much water is expected to be taken in the future. This "flood-skimming" of the Connecticut River is a precedent for future action.

One area which was not covered was the administration of the water diversions. It is unclear whether the Corps will be in charge or not. Further, what control procedure will be used to insure that flood skimming only occurs on days when the minimum flows have been reached?

Section 2. No Comment

Section 3. What will be the impacts of future actions for which this is a precedent? If we continue to take incremental quantities, each diversion will be a decrease of perhaps acceptable relative amounts; however the concern should be what is the maximum amount of water which can be diverted and yet still have a healthy river. Environmental effects would be one factor in that determination.

Why was 17,000 CFS chosen as the lower limit of flow acceptable for skimming? Was this determined by projected demand for water, or were ecological reasons included? Is the Corps required to follow a State legislative mandate? DEP feels a much broader and greater number of flow levels should be evaluated. As indicated later in the EIS, this is not "flood skimming". The highest recorded CFS on the Connecticut River is in the 200,000 range. From an environmental standpoint, if 17,000 is better than 12,000, wouldn't 20,000, 25,000 or 100,000 be better than 17,000?

Socio-Economic Impacts

The analysis is too narrow. What costs will be associated with the greater concentration of pollutants in Connecticut (P.79)? Further the analysis only considers the costs and benefits to Massachusetts, but not the costs to Connecticut. This must be corrected. In addition, from a water supply standpoint, what will happen when Hartford must use Connecticut River water? The need is forecasted for before the year 2000. Hartford, however, will return the water to the river basin. What is the source data for the costs on the no go option (P. 106)?

Section 4. No discussion of impacts caused by future diversions for which this is a precedent because this project is only a short-range solution.

Section 5. In the case National Resources Defense Council, Inc. v. Morton, ___F.2d__, 3 ERC 1558 (D.C. Cir. 1972), the court found that ". . . the discussion of environmental effects of alternatives need not be exhaustive. What is required is information sufficient to permit a reasoned choice of alternatives so far as environmental aspects are concerned. As to alternatives not within the scope of authority of the responsible official, reference may of course be made to studies of other agencies--including other impact statements." (Emphasis added)

No Action. Only losses were considered. Benefits should also be considered.

Desalination

As stated on P. 121, desalination could be a long-range solution to the M.D.C.'s

problems. However the analysis in this section gives it inadequate consideration. The costs and benefits were not delineated, nor were any benefits presented.

The fact that a long-run solution was found would be a major benefit in itself. The present proposal is only a short-range solution--in ten years the problem will have to be dealt with again. Further the cost of water from the proposed plans is artificially low because M.D.C. is not paying for any costs caused by the diversion downstream. With desalination the people getting the benefits would also have to pay the costs.

Importation. No Comment

Waste Water

It is mentioned as a potential source of industrial water, but then is left insufficiently developed.

Ground Water

No cost/benefit figures were presented, so outside observers could not make a rational choice.

Dual Water Supply Systems

Insufficient information is given on costs and benefits.

Other Diversion Sites

A. No Comment

B. Merrimack River. Again costs and benefits are inadequately presented. This appears a reasonable choice for two reasons: (1) there is potential for long-run water supplies and (2) the river is closer to those who will benefit by the diversion.

Sudbury. Same inadequacies as above.

Water Demand Control

A. The data on the user area is inadequate. The EIS says national data is quite different than this region.

B. Were any efficiency studies done to determine how much of the current water is wasted in the MDC area? An educational campaign could reduce that segment and decrease future demand requirements. Modification of new construction building codes should have been considered. DEP agrees the present elasticity data is weak; however since the Army Corps is involved in several water supply projects, it should fund some water elasticity studies.

Since the Corps is involved with federal funding, some alternatives may be chosen, not because they are the best, but because outside funding is available only for certain options. Which of the alternatives presented would the Corps help finance and which ones not?

Was any consideration given to a water rate which increases with water consumed? This is an alternative that should be considered.

Restrictions

The analysis was not developed fully. As we have seen, growth has costs as well as benefits.

Release Schedules. No comment

Population Zoning and Regulations

The definition as well as the analysis of this area is inadequate.

Section 6. Donor and receiver systems are in Massachusetts, but any damage to the river would occur downstream. A cost/benefit analysis should be presented.

Section 7. DEP feels these diversions are permanent considering projected future shortages in 10-20 years. Further, this is an irreversible commitment of future diversions from the river basin since no ceiling has been determined for the river.

Conclusion

DEP reiterates its position that this is an action which definitely sets a precedent for future diversions out of the river basin. Furthermore the DEP feels that this project should be held up until a regional agency such as the New England River Basin Commission can be empowered to determine the allowable amount of water that can be diverted from the Connecticut River and to allocate that quantity of water amongst the states in a mutually agreeable way.

At your service,

Dan W. Lufkin
Commissioner

DWL:bw

STATE OF CONNECTICUT
DEPARTMENT OF FINANCE AND CONTROL
PLANNING AND BUDGETING DIVISION
340 CAPITOL AVENUE - HARTFORD, CONNECTICUT 06115

January 2, 1974

Mr. John W. Leslie, Chief
Engineering Division
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

In June I transmitted to you preliminary comments by technical staff of departments of the state resulting from the review of the draft study reports of the Northfield Mountain and Millers River diversions prepared by your office. As suggested at that time there was a follow-up meeting held in August between representatives from your planning office and the staff representatives of the several state agencies involved. This meeting was held under the auspices of the Interagency Water Resources Planning Board (IWRPB) which is made up of representatives from the several agencies participating in the review of these reports; namely, Department of Environmental Protection, Department of Health and the Planning and Budgeting Division of the Department of Finance and Control. That meeting provided opportunity for further discussion and some clarification on a variety of matters raised by the review agencies and communicated in the initial memos. It was determined that further review and discussion among the several state agencies would take place and result in the submittal to your office by the IWRPB of a consolidated statement representing the summary of technical reactions from these agencies to these proposed projects. Set forth below and in the attached is the result of this review process consolidating the concerns of the several agencies which work together as the Interagency Water Resources Planning Board.

In general there is consensus that the basic objective of the studies appears to be limited to establishing "justification" for specific preconceived projects rather than a comprehensive and objective effort to seek the best long range solution to a water supply problem while considering all concomitant water resource management concerns. Because of this limitation in approach, there is a general impression of: inadequacies and bias in the consideration of alternatives to the selected projects; a narrowness, short-sightedness and imbalance in cost-benefit analysis; and a glaring lack of consideration of competing demands and needs particularly outside of the Boston metropolitan area.

From the point of view of the technicians from Connecticut involved in this review, the most serious shortcoming of the study is the disregard for long range costs which will have to be paid by Connecticut for these inter-

basin transfer projects and subsequent similar projects which can be anticipated as a result of this approach to the water supply problems of the Boston metropolitan area. These potential costs to Connecticut interests are summarized in the attached staff paper prepared by the Connecticut Department of Environmental Protection entitled "Interbasin Transfers of Interstate Water, Current Authorities and Processes, October 1973". The fact that fully documented dollar assignments cannot be made at this point in time does not make these any less real as direct and indirect costs of these projects and in no way justifies that they be ignored in considering the feasibility of these and subsequent removals of water from the Connecticut River Basin.

On Page 66 of the Essex Marine Lab Report it is stated:

> Because of the paucity of the data in some critical areas of basic biology pertinent to the problem considered herein, no absolute prediction can be made regarding the ultimate fate of microorganisms in an estuary subject to changes in salinity and/or temperature. Since, however, the changes are likely to be relatively small (i.e., 2°F and less than a few parts per thousand salinity) at any given point and will develop over a period of time, no significant qualitative or quantitative alterations in bacterial populations can be presumed to occur within the short run (a few years). Beyond this span no opinion can be offered. Current information on other organisms (algae, protozoa) is suggestive of potentially more rapid alterations in community structure in affected areas over a shorter period of time.

We feel that the above lack of knowledge for predictive purposes is crucial for the evaluation of the overall affect of the proposed diversions. Microorganisms algae and protozoa are low in the river food chain and even slight changes in their populations are multiplied higher up in the food chain. We feel it is an important inconsistency in the Essex report to indicate great uncertainty concerning effects on organisms low in the food chain and then state with apparently great certainty that the effect on other animals higher in the food chain, such as anadromous and resident fish, will not be significant.

It is the further consensus of the reviewing agencies that such projects involving transfer of waters out of the basin of an interstate river system cannot be justified without consideration of the legal/institutional mechanisms for protecting all of the interests in those waters. As a minimum it is felt that projects such as these should not be implemented on a unilateral basis without regard to the needs, plans and programs of downstream interests. In addition, they should not be implemented without provision for monitoring of deleterious effects downstream and the opportunity to require operational adjustments as may be found necessary to alleviate harmful impacts downstream as these may be identified in the future.

The IWRPB of Connecticut, in light of the variety of direct concerns indicated in the attached staff paper, recommends that the subject reports be supplemented by comprehensive analysis of legal/institutional implications and needs relative to these and subsequent projects involving interstate waters. In particular it is recommended that there be analysis of the feasibility of the following.

59-652 O - 80 - Vol.II - 38

Establishment of an interstate agency or organization which would have clearly defined responsibilities and powers relative to proposals involving interbasin transfers, diversions and/or impoundments of interstate waters in New England. Basic responsibility of such organization would be in providing control over the allocation of interstate water resources to ensure the proper consideration of the interests of all affected states. To carry out this responsibility the organization, at a minimum, should be delegated adequate powers to:

1. Comprehensively and objectively study the basin as an interrelated whole and develop predictive ecological modeling of the basin.

2. Require complete evaluation of all alternatives to any proposed diversion or interbasin transfer of interstate waters.

3. Establish and enforce standards for interstate waters relative to minimum flow, amounts and times of diversion, and any other matters affecting downstream interstate interests.

4. To require a comprehensive program of monitoring of downstream effects, both physical and biological with particular emphasis on micro-organisms and the food chain, of projects undertaken on interstate waters and to establish and enforce operational standards designed to correct harmful downstream effects identified in the monitoring program.

5. To receive, review, impose reasonable standards and conditions or veto any proposed project affecting interstate waters after consideration of all interstate costs and benefits.

6. To comprehensively coordinate the variety of agencies, organizations, activities, etc. which are presently involved in various activities in the Connecticut River Basin. By listing the above items we do not mean that they should necessarily be solely performed by the above proposed interstate organization, nor do we advocate that any redundant actions be taken. Rather, we are listing the areas of concern and we would assume that any organization which is constituted would draw on both the work accomplished and expertise of other organizations.

We appreciate the opportunity given us for review of these reports and trust that the thoughts above will be taken into account in future work by your office. Also, it is requested that when the final project proposal is prepared, that it be submitted to Connecticut for review and comment.

Sincerely,

Harold I. Ames
Chairman - Interagency Water Resources
Planning Board

HIA:ba

Attachments

STAFF PAPER

INTERBASIN TRANSFERS OF INTERSTATE WATER

Current Authorities and Processes

October 1973

Connecticut

Department of Environmental Protection

INTRODUCTION

This report is being prepared by the Connecticut Department of Environmental Protection for the New England River Basins Commission (NERBC) and is intended to serve two basic purposes --

- o re-affirm Connecticut's concern about the diversion of water from the Connecticut River Basin (or any interstate river)
- o research and analyze the existing authorities and methods to evaluate and arrive at decisions concerning water allocations and diversions.

In the preparation of this report, the NERBC's two excellent staff reports, "A Historical Perspective on Connecticut River Basin Diversion Proposals" and "An Analysis of Some Considerations Appropriate to Formulating a Mechanism for Administering Diversions of Connecticut River Basin Waters" were most helpful.

The concern of the Connecticut Department of Environmental Protection (DEP) about this project began shortly after the Department's creation. Former Commissioner Dan W. Lufkin, on January 12, 1972 in a letter to Frank Gregg of the NERBC, made three points related to proposed diversions from the Connecticut River, Northfield Mountain, and Millers/Tully, with regard to the 1980 Connecticut River Basin Plan. He endorsed:

- o the recognition of riparian rights of downstream interests, should the proposals be undertaken, including the right of return of the waters when needed for water supply or flow augmentation
- o the creation of an interstate mechanism for analyzing in- and out-of-basin water diversions considering ecological effects and alternative water supply sources
- o the need for a comprehensive predictive ecological model of the Connecticut River Basin to evaluate "flood-skimming" of "excess" waters

The above comments have served as the basis of the DEP's and the State's comments both to the NERBC and the U.S. Army Corps of Engineers (Corps) on their subsequent draft Environmental Impact Statement (EIS) and New England Water Supply (NEWS) and remain at the center of our recommendations on these projects.

CONNECTICUT'S CONCERNS REGARDING INTERBASIN TRANSFERS

Hydrology

The hydrologic cycle involving precipitation-infiltration-runoff is an

interrelated physical process occurring within a drainage basin. Diversion of water from one basin to another alters the cycle by depriving one area of runoff water and introducing it into another; negative environmental effects associated with out-of-basin diversion generally do not affect the recipient, but rather the donor. It is for the implications rendered by hydrologic cycle alteration that the State of Connecticut requests the formation of a basinwide authority to oversee diversion proposals.

The Connecticut River regime has over time adapted to various alterations, most of which have been manmade. A comparison of the number of days of flow exceeding 17,000 cubic feet per second at the U.S. Geological Survey gaging station at Montague City, Massachusetts shows this figure to be fairly constant since 1929, oscillating about a figure of 80 days. The implications of such an observation are that the effects of urbanization, i.e., increased peak flow height and frequency, are being counteracted by the various flood control structures placed by man in the basin. Controls placed by man on the river, for example, "flood-skimming" and diversion, have effectively put the river between artificial bounds set by man, with these limits being narrowed with each additional control mechanism which is proposed and subsequently developed. The functions of a river, both hydrologic and ecologic, will not adequately be met in the future if such stringent parameters continue to be set.

One of the primary hydrologic functions of a river or stream is recharge of its banks and flood storage areas so that in times of low flow, reversal can occur resulting in stream flow augmentation. Out-of-basin diversion through flood-skimming removes runoff water which would otherwise overflow the channel and infiltrate into the groundwater system. This overflow process also serves to improve water quality; silt, heavy metals, toxins and other water contaminants are deposited or adhere to deposits and are thereby removed from the stream.

River systems also serve to carry away the results of land surface erosion. Above normal siltation is a major problem resulting from increased development within the basins. Removal of water from a stream during flood periods, when stream load is the greatest, decreases the total volume of water available to transport the amount of silt which will be introduced into the system. The load-carrying capacity of the stream decreases and siltation of the channel results. Freshet flows, if unaltered, serve to scour channel bottoms while at the same time depositing silt over the channel where it can be utilized for such purposes as agriculture and wetland generation. When the freshet subsides, a fresh load of silt is deposited on the channel bottom.

A further implication of out-of-basin diversion involves water depth. Removal of incremental amounts of water lowers the main channel depth by an amount which may seem negligible, but, as a result, the main stream tributary channels drop in depth, a process similar to estuary behavior in response to tides. A six inch decrease in the level of a main stream results in a similar tributary drop where the economic and ecologic results will occur more severely and quickly.

Riverine Ecosystems

At the present time, a serious consideration of the ecological changes associated with out-of-basin diversions is largely limited to extrapolative arguments. There is little basic research dealing with the issue, and we must build our predictions on quite limited data bases.

The case in point at the present time is the proposed diversion to Quabbin Reservoir (and ultimately, Boston) of the flood peaks on the Connecticut River and its tributaries the Millers and Tully Rivers when the flow is greater than 17,000 c.f.s. on the Connecticut River at Montague City, Massachusetts.

The ecological impacts of the proposed diversion have been studied by the Essex Marine Laboratory staff, whose report has been incorporated into Volume IV appendix J of the Northeastern United States Water Supply Study. After quite thorough analysis, they arrive at the conclusion that the effect of the proposed 17,000 c.f.s. diversion will be unmeasurably small in the lower river reaches. While this report deals thoroughly with the benthos, the microbial association, and the fish community, they were unable to clearly delineate the interactions between the various parts of the riverine ecosystem, and the report failed to deal with the floodplain plant community, which may well be the part of the system most sensitive to change in the flooding regime.

The point to be made at this time is that an event-centered viewpoint is inadequate to deal with ecological questions like this one. The event-centered viewpoint dictates that we examine the proposed diversion, and accept or reject it based on its measurable effects. We must examine the question from a more refined level, taking into account factors such as cultural inertia and the effects of such usage extrapolated to greater degrees.

Cultural inertia will produce a rationale such as the following: "We diverted the peak of the flood, it had very little effect. Certainly, we can divert a bit more of the peak with no harm...and a bit more...and a bit more..." The extrapolated usage factor is a second-crder phenomenon based on the above. The predicted outcome is quite clear - a major river with severely damped annual oscillation in flow rate with the hydrologic and water quality impacts discussed in other sections.

This expanded point of view, coupled with the repeated conclusion of the Essex Marine Lab that a great deal more study needs to be done (we know little about riverine ecosystems) leaves us with the conclusion that the diversion of flood peaks may well be a very risky proposition.

Ecosystems are intricately balanced, evolved entities. Organisms living in given physical systems (e.g. a floodplain, a river channel) are delicately tuned in four dimensions to each other and the variations in their physical environment. This has been shown in a multitude of ways with riverine ecosystems -- for example, the various habitat preferences for bottom-dwelling (benthic) organisms - with different associations of organisms determined primarily by current velocity. Another example is the work done by C. Stone (M.S. thesis, Boston University, 1972) which showed floodplain vegetation distributions which are a function of the frequency of flooding. An idealization of the distribution is that certain plant species are more capable of withstanding inundation of their root systems than others. The plant species then, arrange themselves within their competitive matrix according to the resultant between the frequency of flooding and their tolerance to same. Generally speaking, one finds the more flood-tolerant species closest to the river channel, with the less tolerant species further upland. In the

eventuality that flooding is reduced (as it would be in any diversion case) the zones of flood tolerant species would effectively "shrink", the extent of such shrinkage a function of the degree of flood reduction. Obviously, animal habitats will be concomitantly altered.

In conclusion, the narrow prove-its-effect point of view is simply inadequate with regard to incremental interbasin diversions; we must look at the question in the most comprehensive manner possible, weighing the lessons of history with regard to man's effect on environmental quality and our knowledge of riverine ecology with the demands for water.

Water Quality

The Connecticut River is classified in Connecticut's water quality standards as Class B - suitable for swimming and other purposes and Class C - suitable for fishing and other purposes. Each of these classifications contain criteria which must be met in order to realize these uses. The D.E.P. is concerned with possible direct and indirect effects stemming from the proposed Northfield Mountain and Millers/Tully diversions which might limit Connecticut's ability to reach, maintain, and improve these water quality objectives. Although the proposed projects involve alteration of natural flows during freshet periods, it must be noted that direct and indirect water quality benefits from natural freshet flows have not yet been quantified on the Connecticut River. Thus the D.E.P. believes the applicant should initiate monitoring and research on the tidal and non-tidal portions of the river as a condition to proceeding with this project.

Such research should address the decreased capacity of the stream to attain the chemical, thermal, and dissolved oxygen criteria for classifications B and C.

Possible existing benefits resulting from freshet conditions such as flushing of sediments and biological dependence should be defined quantitatively if possible. Freshet benefits associated with assimilation of combined sewer discharges occurring in Connecticut and Southern Massachusetts should also be assessed. Also, potential changes in the salinity gradient in the estuary should be evaluated.

In view of possible future expansions of Connecticut Yankee Atomic Power Plant facility and new proposals on the Connecticut River, a direct interest of the D.E.P. would be an assessment of the streams decreased capacity to assimilate new or expanded thermal loadings on the Connecticut River.

The D.E.P. recognizes the comprehensive nature of such a task and feels that it is essential that data be provided in order that we may assure the citizens of Connecticut that the adopted state water quality standards will not be jeopardized, particularly in the event that expansions of this proposed diversion are involved in the future. We would be pleased to cooperate and to provide some assistance in the development of such research and monitoring, and point out that funds have been authorized under Section 104 of the Federal Water Pollution Control Amendments of 1972 which are applicable in part to the research outlined herein.

Water Supply

The conflict of in-basin usage of water versus out-of-basin diversion appears most immediately when the question of water supply is discussed.

The Boston metropolitan area, supplied by the Metropolitan District Commission, has a greater demand for water than is presently available in stored supply. The source to which MDC first turned when the Quabbin Reservoir was constructed was the Swift River, a tributary of the Connecticut River. Connecticut's objections were overturned in court in 1930 (Connecticut vs. Massachusetts, 282 U.S. 660) when a master appointed by the Supreme Court reported that the State of Connecticut could show no immediate need of a water supply from the Connecticut River and that the Boston area could indeed show that it needed water. The State of Connecticut also could not adequately show that any other damage was being done to the Connecticut River flood plain and ecosystem by flood-skimming of the Swift and Ware Rivers.

Massachusetts again thought of the Connecticut River basin in the late 1960's when the eastern part of the state was threatened with a water shortage. They proposed a series of Connecticut River and tributary diversions which would "flood-skim" basin water and divert it out-of-basin to eastern Massachusetts. The State of Connecticut is again voicing concern to the proposed out-of-basin diversions by the Boston MDC. It appears that the MDC believes tha Connecticut River basin is the long term solution for its water shortage problems. We know that this continuing precedant of diverting Connecticut River water to meet MDC's demands will be harmful to the river and to the river basin residents in Massachusetts and Connecticut.

The Connecticut Capitol Planning Region Report on water supply and other utility usage states that 55 million gallons per day (mgd) will be needed from surface water supplies to meet the year 2000 demand. The report states that the future water sources should be derived from "...clean upland sources, using the Connecticut River as a final source to make up any deficiencies required." It was projected that the Capitol Region will need from 5 to 55 mgd of Connecticut River water at this time. Of course this water is not removed from the river basin.

The only other regional planning agency which has to this date proposed utilizing the Connecticut River for water supply is the Lower Pioneer Valley Regional Planning Commission, centered in West Springfield, Massachusetts. They have proposed using the Connecticut River if the cost of upland water development becomes excessive or if the water becomes unavailable. A report on water supply suggests the possible development of a diversion on the river above the Holyoke Dam.

The remaining regions located along the Connecticut River have not yet made projections which involve utilization of the river water, but this does not preclude the possibility of future need. Many regional authorities have simply not projected their requirements far enough to consider use of structures or sources other than those presently in use. The Army Corps of Engineers and Boston Metropolitan Commission infer, through their diversion proposals, that surplus water conditions exist on the Connecticut River. It should be their responsibility to support this proposition. This "surplus"

may in fact exist at present, but future expectations that this will continue to be the case may be unfounded because of inadequate or incomplete projections by regions within the river basin.

It seems clear that the Connecticut River Valley may need the water of the river for their own supplies and find that not enough is available or the quality unsuitable because of upstream, out-of-basin diversions. This possibility can be avoided by proper surveillance and allocation by a regional group authorized to oversee activities in the Connecticut River Basin.

The Proposed Plan of Conservation and Development

The State of Connecticut has recently published a "Proposed Plan of Conservation and Development", presenting suggestions for future state land-use policies. The "Plan of C & D", when officially adopted by the state, will define the direction Connecticut will follow in the protection and conservation of its natural resources.

Policy number three of the "Proposed Plan of C & D" deals with protection of the scenic, historic and natural resources of Connecticut. Section 3c states that the State should "Give full support to the conservation of the natural beauty and historic character of the Connecticut River Valley".

Diversion of the Connecticut River removes water from the hydrologic cycle inherent to the Connecticut basin and in this way alters the natural manner in which the river functions. Continued manipulation of the river threatens to destroy those natural resources associated with a river ecosystem; wetlands face dry-ups; aquifers no longer recharge; wildlife lose protective shelter; aquatic life see changes in its living habitat; and channels fill with silt from unloading. The beauty for which the Connecticut River Valley has historically been known should be saved at all costs.

Connecticut has begun implementing the section of the "Plan of C & D" concerning conservation. The Cashman Bill, An Act Concerning the Preservation of the Lower Connecticut River Area, Public Act 73-349, provides for open space and scenic preservation of the lower river valley, from Middletown to the estuary. To be successful, this effort must be supplemented by assistance from upriver states; proper water quality and quantity are essential to preservation efforts, ensuring that degradation of the water resources of the area will not continue, but will improve with time.

The State of Connecticut is opposed to any alteration or threat to the natural resources of the Connecticut River Valley. Adequate protection is best realized through joint interstate, state, and local efforts to limit the quantity and types of development and exploitation.

WATER SUPPLY ALTERNATIVES

Out-of-basin transfer of Connecticut River water is not the only existing method through which Boston can obtain needed water. If Connecticut

River water were unobtainable or unavailable, the Boston MDC could meet equirements through one or more of a list of alternatives mentioned by the Corps of Engineers in their New England Water Supply Study.

The largest quantity of readily available water in the Boston area is groundwater located south of the metropolitan area in Plymouth County and Cape Cod. Both of these areas have 300 million gallons per day (mgd) of groundwater available, according to the U.S. Geological Survey (USGS); the Corps of Engineers has said that only 150 mgd can be "safely" taken from Cape Cod, but Plymouth County does indeed have 300 mgd.

The Corps reported in its study that Cape Cod will very shortly require the 150 mgd of available groundwater to meet its own needs, but affirmed that 300 mgd could "possibly" be taken from Plymouth County, if the surficial projections of USGS prove to be accurate. Both the Corps and Boston MDC have eliminated Plymouth County groundwater as a feasible alternative to Connecticut River diversion because the economic costs of this groundwater development are roughly twice that of diversion. The major economic cost of development is piping, which must extend from Plymouth County to near the Boston area.

The diversion would use an existing aqueduct from Quabbin to Boston. However, while the economic costs favor the diversion, its environmental effects are greater than groundwater development. The diversion and wellfield will require an aqueduct and pipeline, respectively, and will result in short term construction impacts. Over the long term the diversion will result in many environmental effects with related costs: fish, waterlife and plant entrainment at the Northfield Mountain intake and the environmental effects discussed in an earlier section resulting from reduced freshet flows in the Connecticut River. The effects of the groundwater development over the same period are minimal.

A major discrepancy surfaced on the subject of costing groundwater well development; USGS quoted single well construction and development at $10,000 per well, whereas the Corps said this figure should be closer to $100,000 per well. The variance by a factor of ten in pricing wells is still unsolved, and remains a critical item for future discussion of groundwater development as a feasible alternative.

Another alternative is the development of diversions closer to the Boston area. This would be more equitable because the recipients of the benefits are assessed the environmental costs. The diversion of the Merrimack River is included in the Corps of Engineers' NEWS study. Further, it is currently being analyzed by the Corps, with the results available in September of 1974.

Population and growth projections based on historical trends for the next twenty years indicate that the metropolitan area of Boston will continue to expand, resulting in an increasing water demand. There will come a time when the present aqueduct from Quabbin Reservoir will no longer be capable of transporting the water needed by Boston; at this time, money will have to be expended by MDC to either expand the aqueduct or seek another alternative. Groundwater development and Merrimack River diversion would seem feasible and economically compatible alternatives to consider when a decision to expand must be made.

Another alternative to interbasin diversion is water demand control, as suggested in the Corps' NEWS study. Dual water supply is feasible if applied to a heavily industrialized area, thus decreasing the demand for more potable water from Quabbin Reservoir. Demand could be further lowered through education of the consumer in the conservation of water. Approximately 90% of water demand in the Boston area is for non-industrial use; simple practices such as turning off faucets and not watering lawns frequently would decrease demand. Metering and pricing are also means to reduce industrial and non-industrial demand; these are especially favorable because the recipient of the water benefits will have a financial incentive to conserve water.

If demand modification is not utilized, in approximately twenty-five years the ability of the Quabbin to Boston transmission system to meet demands will be exceeded; at this time, alternatives presently classified as not feasible may appear more attractive and merit further consideration. A better cost/benefit figure may arise for an alternative proposal to Connecticut River diversion. Connecticut believes that water conservation measures should be initiated and serious consideration should be given alternatives closer to the recipient area when the next stage of review arrives.

EXISTING AUTHORITIES AND PROCESSES FOR RESOLVING INTERSTATE RIPARIAN DISPUTES

The U.S. Supreme Court has original jurisdiction in all disputes between states. The Court acts in the capacity of a trial court, although it never takes evidence itself. A Special Master is appointed to hear the evidence, prepare findings of fact and conclusions of law and recommend a decree. The Court then considers the Master's Report, writes an opinion and enters a decree. The Supreme Court has indicated its reluctance to adjudicate interstate stream disputes and has urged parties to resolve their differences by compact.

There have been two major interstate reparian disputes between eastern states -- New Jersey v. New York, 283 U.S. 336 (1930) and Connecticut v. Massachusetts, 282 U.S. 660 (1931). The opinions expressed similar riparian doctrines. The New Jersey v. New York decision is best noted for Mr. Justice Holmes' often quoted observation that "a river is more than an amenity, it is a treasure." With that in mind the Connecticut v. Massachusetts case will be discussed as the opinion contains a lucid analysis of interstate riparian law and the factual situation is pertinent to the matter under consideration.

In that case, Connecticut sought to enjoin Massachusetts from diverting water from the Swift and Ware Rivers which are in the Connecticut River watershed. The proposed diversion included the flood waters of the Ware in excess of 85 million gallons per day during the period from October 15 to June 15 and all waters from the Swift subject to the maintenance of certain minimum flows.

Connecticut sued as the owner of riparian lands and of the riverbed and as parens patriae for citizens threatened with injury as a result of the diversion. Connecticut alleged that the diversion would impair navigation, cause damage to agricultural lands that are yearly inundated by flood waters,

prevent the dilution of pollutants in the river and adversely impact anadromous fish runs. The state claimed that alternative water supplies could satisfy the demand which motivated the proposed diversion. Massachusetts denied that any injury would result claiming that the impact of the diversion would be negligible and that the project would stabilize the flow of the River benefiting Connecticut.

The Supreme Count appointed a Special Master who took evidence in the case. The Master determined that Boston faced a serious water shortage and found no interference with navigation. Connecticut failed to prove the other alleged environmental impacts to the Master's satisfaction.

The Court adopted the Master's findings and declined to provide the requested relief. The Court was reluctant to exert its extraordinary power to control the conduct of one state at the suit of another unless the threatened invasion of rights was of serious magnitude and established by clear and convincing evidence.

As the Court put it, "the burden on Connecticut is much greater than on one seeking an injunction in a suit between private parties." Connecticut v. Massachusetts, 282 U.S. 660, 669 (1931).

The principle of riparian common law holds that each riparian owner has a vested right in the use of flowing waters and is entitled to have them flow undiminished in quality and quantity.

Connecticut asserted this common law riparian right. The contention was rejected by the Court which held:

> The determination of the relative rights of contending states in respect of the use of streams flowing through them does not depend upon the same considerations and is not governed by the same rules of law that are applied in such states for the solution of similar questions of private rights. Id at 670.

Interstate riparian disputes are settled on the basis of equality of right which means that the principles of right and equity are applied having regard to the, "equal level or plane on which all the states stand in point of power and right under our constitutional system". The Supreme Court applied this principle of equitable apportionment in holding for Massachusetts.

The principle of equitable apportionment has become the standard applied in interstate riparian litigation. The Court in applying the principle considers a number of factors including physical and climatic conditions, the consumptive use of water on the river, the character and rate of return flows and the extent of established uses. The Supreme Court will not adjudicate an interstate water dispute until existing consumptive uses in one state cause harm or threaten harm to another state.

The Connecticut v. Massachusetts opinion with its reference to the principle of equitable apportionment is significant in that it illustrates the Court's reluctance to adjudicate such disputes and indicates the principles to be applied in similar cases.

Connecticut Authority.

The following statutory authority has been conferred on the Attorney General and the Commissioner of Environmental Protection with respect to the diversion of interstate water resources. The Attorney General is authorized:

1. to negotiate and contract, with the Governor's approval, with any commission appointed by another state concerning allocation or diversions of streams flowing through Connecticut Section 3-127 Connecticut General Statutes (C.G.S.)

2. to investigate and, with the approval of the Governor, take any action deemed necessary to protect the state from damage by diversions of streams flowing through Connecticut Section 3-126 C.G.S.

The Commissioner of Environmental Protection is authorized to:

1. represent the state in negotiating and entering into agreements or compacts with authorized agencies of other states and/or the federal government concerning pollution and diversions of interstate waters Section 25-3 C.G.S.

2. submit any agreements or compacts so developed to the Governor and General Assembly for approval Section 25-4 C.G.S.

Therefore further discussions between states concerning the institution of an interstate mechanism should be undertaken by Connecticut through the joint efforts of the Department of Environmental Protection and Attorney General. After negotiations are completed, the agreement will have to be approved by the Governor, and depending on the type of agreement, the General Assembly.

Analysis of Existing Processes.

With regard to the existing process of communication and decision-making for interbasin transfers of interstate waters, a distinction must be drawn between the Corps of Engineers' New England Water Supply study (NEWS) and the Massachusetts Metropolitan District Commission (MDC) process. While superficially the Corps and the MDC appear to be unanimous in their plans for the Connecticut River, upon closer inspection it can be seen that they have independent plans which are proceeding in a nearly parallel fashion. It is not coincidence that their plans are similar--there has been coordination between these parties. Nevertheless two examples will show the extent of the independence of these two agencies. The MDC already has the authority and funding from the Massachusetts Legislature to move ahead on their own in implementing the diversion at Northfield Mountain should the NEWS proposal be delayed or stopped. The NEWS proposal considers the diversions at Northfield Mountain and Millers/Tully Rivers to be a single project; however the MDC is now planning on the Northfield project only with implementation of Millers/Tully in the future, if ever. One point of commonality of the two agency proposals at Northfield Mountain is that the Northeast Utilities must obtain a license amendment from the Federal Power Commission (FPC) as a prerequisite

implementation.

Because of the independent yet parallel plans of these two agencies, their communications and decision-making processes will be considered separately. The NEWS study contained a formal process for communications and decision-making. Connecticut, along with other states, appointed Coordinators to the Study, and regular progress and discussion meetings were held. In addition, we were constantly kept up-to-date with the individual research studies contracted under the study.

The NEWS decision-making process followed from their communications. Connecticut was able to express its point of view, which was received courteously. Nevertheless, in the final analysis, the U.S. Senate Committee on Public Works had authorized the Corps of Engineers to make a study and prepare a final recommendation for them. Connecticut faults this process because it was not given a share of the decision-making authority and responsibility. As the downstream state which receives no benefits and all the costs, Connecticut must have a greater input into the decision-making process.

The analysis of communications and the decision-making process of the MDC is based on a retrospective study of previous relationships on these diversion proposals. We have had to analyze it in this manner because of a lack of formal processes, such as the NEWS study. This is not to imply that formal procedures are necessary for good information flow. In this case the lack of formal process has left Connecticut unaware of the MDC's plans and methodology. Connecticut was not invited to meet with the MDC planners and not kept appraised of developments. Connecticut's information source was primarily the newspapers. The Connecticut Water Resource Commission (CWRC) had to spend its own money to investigate the hydrologic impact of the proposed Northfield diversion. Nevertheless, Massachusetts has treated us graciously in responding to our questions. In 1966 when the CWRC felt there should be a more open airing of the issue, Massachusetts complied and testified before a public hearing. It is our conclusion that historically the information flow has been nearly nonexistent, and when it has occurred, it has been at Connecticut's request. Connecticut feels a continuation of this process is unsatisfactory. Connecticut and Massachusetts have cooperated on many issues of joint importance to each state such as water quality management on the Quinebaug and French Rivers. As we have learned in those instances, the basis of cooperation is free communication.

Connecticut has had no role in the MDC's decision-making process for these projects of interstate consequence. The one historical example at all related to decision-making was a request from the Director of the CWRC, after the public hearing in June of 1966, that an agreement be drawn up concerning adequate monitoring of the proposed minimum 17,000 c.f.s. flow at Montagne City (or 15,000 at Turners Falls Dam). Massachusetts has not to this date proposed a solution to this request. Although this is not Connecticut's only concern with the projects, it is an example of our involvement in the MDC's process of analyzing water supply sources and their costs and benefits. As stated in the section on NEWS, we are greatly concerned and affected by any significant alteration to the river basin. Therefore Connecticut must be centrally involved in the decision-making process for projects of interstate significance.

Millers and Tully River Diversion as a Case Example.

Previous sections have discussed the existing processes with the NEWS study and the MDC in some detail. It is Connecticut's conclusion that each process has been unsatisfactory with regard to the Millers/Tully proposals. The NEWS study which did not grant Connecticut a decision-making role is moving ahead to propose Millers/Tully for implementation. While the MDC has not proposed the Millers/Tully diversions yet it so far has not involved us in their information flow or decision-making process. Neither of these formal/informal processes has met Connecticut's minimum objectives with regard to the decision to transfer water from the Connecticut River Basin.

We have also discussed Federal and Connecticut authorities and responsibilities over rivers in general. As we indicated there is no federal agency responsible for water supply matters per se. There are agencies with river responsibilities which would be affected by interbasin transfers, but they are only tangentially concerned.

The body of law includes the doctrine of riparian rights to protect downstream interests. As previously indicated, riparian rights are not easily defined. Because it is a part of the body of law without a federal administrative agency, the U.S. Supreme Court remains as the only interpreter of the riparian doctrine between two states. If a case were taken to the Supreme Court, the delays could be quite long, perhaps three to five years.

Connecticut believes that an interstate administrative mechanism could mitigate or solve many of the issues surrounding interbasin transfers. There are four main areas an interstate mechanism could address most adequately:

1. Maintain a constant flow of information between states on water supply plans, needs and problems.

2. Become the central focus for a comprehensive concern for the Connecticut River. It should monitor the river effects of the proposed diversions, if implemented. In conjunction with this, it would coordinate, finance or conduct basic research on riverine ecology to understand better the effects of the diversions and provide an adequate data base for future proposals on the river whether water supply diversions or flood control, water quality, etc.

3. Provide a forum for mutual decision-making regarding a river of great interstate importance.

4. Avoid the delays of litigation in the U.S. Supreme Court.

Conclusion

This report has covered several points:

- a delineation of Connecticut's hydrologic, ecologic, water quality, water supply, and land-use concerns with diversion of water outside of the Connecticut River basin.

- a discussion of alternatives to interbasin transfers of interstate waters.

- a review and analysis of the authorities and processes available to Connecticut with regard to upstream interbasin diversions with the proposed Millers/Tully diversion presented as a case example.

This report is an important first step. All involved parties should move forward to review and analyze these reports and then discuss the type of orderly process that should be established for making decisions concerning diversions and withdrawals from the Connecticut River Basin.

THOMAS J. MESKILL
GOVERNOR

STATE OF CONNECTICUT
EXECUTIVE CHAMBERS
HARTFORD

January 3, 1974

Colonel John H. Mason
Division Engineer
Department of the Army
New England Division
U. S. Army Corps of Engineer
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Mason:

I am writing to you to express my concern about proposed projects which would transfer waters out of the Connecticut River Basin for water supply purposes by using facilities at Northfield Mountain and Millers River. Concerns of the State of Connecticut on this subject have been previously expressed to your organization in staff reviews and are also discussed in the enclosed letter from Harold Ames to John Leslie of your staff which summarizes results of an interagency staff review of technical study reports for these projects.

Of prime concern to me and to the State of Connecticut is the establishment of an interstate mechanism which would ensure that the interests of Connecticut and any other affected states would be given proper consideration. By copy of this letter I am directing the Department of Environmental Protection to confer with the Attorney General, the New England River Basins Commission and other appropriate parties to determine the steps necessary to proceed in this direction.

I feel it is imperative that as further work proceeds on the study of these projects and as further reports are prepared the State of Connecticut be given full opportunity to review and comment thereon. Therefore I urge that you insure that I am kept fully advised as further actions are taken.

Sincerely,

Tom Meskill

GOVERNOR

TJM:swj
Enclosure
cc: Commissioner Costle, Department of Environmental Protection
Attorney General Killian
New England River Basins Commission
The Honorable Francis Sargent, Governor of Massachusetts

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Mr. John W. Leslie, Chief
Engineering Division
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

In June I transmitted to you preliminary comments by technical staff of departments of the state resulting from the review of the draft study reports of the Northfield Mountain and Millers River diversions prepared by your office. As suggested at that time there was a follow-up meeting held in August between representatives from your planning office and the staff representatives of the several state agencies involved. This meeting was held under the auspices of the Interagency Water Resources Planning Board (IWRPB) which is made up of representatives from the several agencies participating in the review of these reports; namely, Department of Environmental Protection, Department of Health and the Planning and Budgeting Division of the Department of Finance and Control. That meeting provided opportunity for further discussion and some clarification on a variety of matters raised by the review agencies and communicated in the initial memos. It was determined that further review and discussion among the several state agencies would take place and result in the submittal to your office by the IWRPB of a consolidated statement representing the summary of technical reactions from these agencies to these proposed projects. Set forth below and in the attached is the result of this review process consolidating the concerns of the several agencies which work together as the Interagency Water Resources Planning Board.

In general there is consensus that the basic objective of the studies appears to be limited to establishing "justification" for specific preconceived projects rather than a comprehensive and objective effort to seek the best long range solution to a water supply problem while considering all concomitant water resource management concerns. Because of this limitation in approach, there is a general impression of: inadequacies and bias in the consideration of alternatives to the selected projects; a narrowness, short-sightedness and imbalance in cost-benefit analysis; and a glaring lack of consideration of competing demands and needs particularly outside of the Boston metropolitan area.

From the point of view of the technicians from Connecticut involved in this review, the most serious shortcoming of the study is the disregard for long range costs which will have to be paid by Connecticut for these inter-

basin transfer projects and subsequent similar projects which can be anticipated as a result of this approach to the water supply problems of the Boston metropolitan area. These potential costs to Connecticut interests are summarized in the attached staff paper prepared by the Connecticut Department of Environmental Protection entitled "Interbasin Transfers of Interstate Water, Current Authorities and Processes, October 1973". The fact that fully documented dollar assignments cannot be made at this point in time does not make these any less real as direct and indirect costs of these projects and in no way justifies that they be ignored in considering the feasibility of these and subsequent removals of water from the Connecticut River Basin.

On Page 66 of the Essex Marine Lab Report it is stated:

> Because of the paucity of the data in some critical areas of basic biology pertinent to the problem considered herein, no absolute prediction can be made regarding the ultimate fate of microorganisms in an estuary subject to changes in salinity and/or temperature. Since, however, the changes are likely to be relatively small (i.e., 2°F and less than a few parts per thousand salinity) at any given point and will develop over a period of time, no significant qualitative or quantitative alterations in bacterial populations can be presumed to occur within the short run (a few years). Beyond this span no opinion can be offered. Current information on other organisms (algae, protozoa) is suggestive of potentially more rapid alterations in community structure in affected areas over a shorter period of time.

We feel that the above lack of knowledge for predictive purposes is crucial for the evaluation of the overall affect of the proposed diversions. Microorganisms algae and protozoa are low in the river food chain and even slight changes in their populations are multiplied higher up in the food chain. We feel it is an important inconsistency in the Essex report to indicate great uncertainty concerning effects on organisms low in the food chain and then state with apparently great certainty that the effect on other animals higher in the food chain, such as anadromous and resident fish, will not be significant.

It is the further consensus of the reviewing agencies that such projects involving transfer of waters out of the basin of an interstate river system cannot be justified without consideration of the legal/institutional mechanisms for protecting all of the interests in those waters. As a minimum it is felt that projects such as these should not be implemented on a unilateral basis without regard to the needs, plans and programs of downstream interests. In addition, they should not be implemented without provision for monitoring of deleterious effects downstream and the opportunity to require operational adjustments as may be found necessary to alleviate harmful impacts downstream as these may be identified in the future.

The IWRB of Connecticut, in light of the variety of direct concerns indicated in the attached staff paper, recommends that the subject reports be supplemented by comprehensive analysis of legal/institutional implications and needs relative to these and subsequent projects involving interstate waters. In particular it is recommended that there be analysis of the feasibility of the following.

Establishment of an interstate agency or organization which would have clearly defined responsibilities and powers relative to proposals involving interbasin transfers, diversions and/or impoundments of interstate waters in New England. Basic responsibility of such organization would be in providing control over the allocation of interstate water resources to ensure the proper consideration of the interests of all affected states. To carry out this responsibility the organization, at a minimum, should be delegated adequate powers to:

1. Comprehensively and objectively study the basin as an interrelated whole and develop predictive ecological modeling of the basin.

2. Require complete evaluation of all alternatives to any proposed diversion or interbasin transfer of interstate waters.

3. Establish and enforce standards for interstate waters relative to minimum flow, amounts and times of diversion, and any other matters affecting downstream interstate interests.

4. To require a comprehensive program of monitoring of downstream effects, both physical and biological with particular emphasis on microorganisms and the food chain, of projects undertaken on interstate waters and to establish and enforce operational standards designed to correct harmful downstream effects identified in the monitoring program.

5. To receive, review, impose reasonable standards and conditions or veto any proposed project affecting interstate waters after consideration of all interstate costs and benefits.

6. To comprehensively coordinate the variety of agencies, organizations, activities, etc. which are presently involved in various activities in the Connecticut River Basin. By listing the above items we do not mean that they should necessarily be solely performed by the above proposed interstate organization, nor do we advocate that any redundant actions be taken. Rather, we are listing the areas of concern and we would assume that any organization which is constituted would draw on both the work accomplished and expertise of other organizations.

We appreciate the opportunity given us for review of these reports and trust that the thoughts above will be taken into account in future work by your office. Also, it is requested that when the final project proposal is prepared, that it be submitted to Connecticut for review and comment.

Sincerely,

Harold I. Ames
Chairman - Interagency Water Resources
Planning Board

HIAsbs

Attachments

NEDED-R 24 January 1974

Honorable Thomas J. Meskill
Governor of the State of Connecticut
State House
Hartford, Connecticut 06103

Dear Governor Meskill:

Thank you for your letter of 3 January 1974 in which you expressed your concern about proposed water supply projects which would transfer water of the Connecticut River Basin to meet needs within Massachusetts. The projects under consideration, which would use facilities at Northfield Mountain and Millers River, have been in the planning stage for several years and are being conducted as part of the Northeastern United States Water Supply Study (NEWS). From the outset of the NEWS investigations in 1967, coordination on every phase of the work has been maintained with your, and your predecessor's, designated state representative.

As you state in your letter, your prime concern is the establishment of an interstate mechanism to insure that the interests of Connecticut and any other affected states would be given proper consideration. Please be assured that throughout our studies, the projects' potential impact on Connecticut and other states has received careful consideration. The projects were designed to remove relatively small amounts of water from the Connecticut River Basin and only during times of high flow. As a result of this design, none of our technical studies revealed significant impacts on downstream uses of the river.

Although the technical studies conducted did not indicate significant downstream impacts, the Corps of Engineers would be pleased to cooperate in any way in the establishment of a mechanism which is desired by the interested states. Work on development of such an interstate mechanism has, in fact, already been initiated. On 10 August 1973, representatives of Connecticut and Massachusetts

Mr. Pronovost/je/215

NEDED-R 24 January 1974

Honorable Thomas J. Meskill

met with members of the New England River Basins Commission and Corps of Engineers to discuss the need for such an interstate mechanism. As a result of this meeting, it was agreed that the states of Connecticut and Massachusetts would submit reports on the utilization of authorities and methods currently available for dealing with diversion issues.

In accordance with the 10 August agreement, Connecticut submitted its input in October 1973. Massachusetts has yet to submit a paper, but recent discussions with that state's officials indicate their paper will be forthcoming shortly. In addition to these state efforts, the Corps of Engineers is preparing cost sharing and institutional options for the projects which will be made available to both states when completed.

An item apart from the question of an interstate mechanism is the Connecticut interagency staff review of the subject reports. A review of the comments submitted by Mr. Harold Ames to Mr. John Leslie of my staff indicates some areas of disagreement to which I feel we must respond. A response is presently being prepared which will be sent to Mr. Ames with copies to your office. I feel, however, that these technical difficulties can be resolved and the larger issue is the need for interstate agreements concerning the projects.

Please be assured that as further work proceeds on these projects I will keep you completely informed of developments. I look forward to working with you and your staff, as well as Massachusetts officials, in order that suitable arrangements concerning these water supply projects may be developed.

Sincerely yours,

PRONOVOST

BERGEN

JOHN M. MASON
Colonel, Corps of Engineers
Division Engineer

IGNAZIO

LESLIE

BURKE

MASON

CF: Mr. R. Frank Gregg, NERBC

Dr. Charles H. W. Foster, Secretary of Environmental Affairs, Boston, MA

CC: Mrs. Quill; Mr. Leslie;[2] Mr. Ignazio; Mr. Pronovost; Engr Div Files

THOMAS J. MESKILL
GOVERNOR

STATE OF CONNECTICUT
EXECUTIVE CHAMBERS
HARTFORD

January 31, 1974

Col. John H. Mason
Division Engineer
Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Mason:

Thank you very much for your letter of January 24, 1974, in response to my earlier letter regarding the proposed transfer of water from the Connecticut River Basin.

I certainly appreciate your taking the time to share your thoughts with me on this important matter.

I am forwarding a copy of your comments to Mr. Harold Ames of the Planning and Budgeting Division of the State Department of Finance & Control.

As always, I am grateful to you for keeping me up to date on your continued efforts to cooperate with Connecticut and the other states which have such a major interest in the work of the Army Corps of Engineers.

With best wishes,

Sincerely,

Tom Meskill
GOVERNOR

TJM:swn
cc: Harold Ames

NEDED-R 1 February 1974

Mr. Harold I. Ames, Chairman
Interagency Water Resources Planning Board
Department of Finance and Control
Planning and Budgeting Division
340 Capitol Avenue
Hartford, Connecticut 06115

Dear Mr. Ames:

I am writing in response to your letter of 2 January 1974 in which you presented the consolidated statement of Connecticut's Interagency Water Resources Planning Board regarding the draft reports of the Northfield Mountain and Millers River Basin water supply projects. I understand these comments supplement those made earlier by you in correspondence dated 22 June 1973. Both sets of comments were made in response to draft reports distributed by the Corps of Engineers in May 1973.

I appreciate the time which you and your staff have expended on this review; however, I feel that I cannot agree with you on certain of your conclusions presented in your latest letter. In reading your letter, I am immediately concerned with your view that the draft reports' basic objective is 'justification' for specific preconceived' projects. To anyone familiar with the history and stepwise approach of NEWS studies within New England, this conclusion appears erroneous.

In every phase of the NEWS investigations, Connecticut's views have been solicited and incorperated into the direction of the studies. In 1968 and 1969, for example, the NEWS Study conducted a feasibility detail study to evaluate potential alternative sources for short and long range water supply needs in southeastern New England (Massachusetts and Rhode Island). Five meetings were held during the course of the feasibility study, and Connecticut was

invited to participate in each of the meetings. Connecticut representation during this period consisted of members of the Water Resources Commission and Department of Health.

In May 1970, following the receipt of comments on the feasibility study, a meeting was held in Boston, Massachusetts, to discuss those feasibility study projects which could be candidates for more detailed study. The consensus of those attending this meeting, including a Connecticut representative, was that both Northfield Mountain and the Millers River Basin projects merited a more detailed evaluation. In accord with the consensus of that meeting, the Corps of Engineers conducted investigations of those projects and other alternatives. The investigations yielded the reports sent to you in May 1973. Representatives from my office have met several times since that date to discuss in detail the material presented in these reports.

Throughout the period May 1970 to May 1973, Connecticut was asked, no less than nine times, to attend progress meetings and add their input to the projects' analysis. The screening and selection procedure used, therefore, in determining those elements which should receive detailed evaluation has, since 1968, included the State of Connecticut's input and direction. It is difficult to comprehend how such a procedure could yield a 'preconceived result.

It is stated in your 2 January 1974 letter that the 'most serious shortcoming of the study is the long range costs which will have to be paid by Connecticut' with the implementation of the Northfield Mountain and the Millers River Basin projects. Such potential costs are described as being summarized in the Connecticut Staff Paper entitled, Interbasin Transfers of Interstate Water, Current Authorities and Processes,' October 1973. It is my opinion that many of the potential costs expressed in that paper do not follow from the facts of the projects under consideration. I have asked my staff to prepare responses to these comments, and they will be sent to you shortly.

I would be pleased to meet with you on this subject at your convenience to discuss each of the points raised in your staff's paper, if you feel such a meeting would be profitable.

The third item of consensus by the reviewing Connecticut agencies noted in your letter is that projects involving transfer of waters of an interstate stream cannot be justified without consideration of the legal/institutional mechanisms for protecting all interests. At a minimum, you suggest diversion projects should consider needed plans and programs of downstream interests and should include a provision for monitoring of any project environmental effects. Please be assured that the Corps of Engineers, in its investigations of the projects under consideration, has given a high priority to the matter of legal/institutional mechanisms. As early as 1969, a study was initiated under contract to determine organizational, legal and public finance aspects of the subject projects as well as other alternatives. From the outset of this study to its publication in July 1972, the State of Connecticut has been requested to participate in this effort.

Initially, the State was asked to aid in the development of the studies' scope of work and later input was solicited during the studies' progress. Perhaps a review of the work included in this report entitled "Organizational, Legal and Public Finance Aspects of Regional Water Supply," prepared by the Institute of Public Administration, July 1972, and a subsequent report entitled "Regional Water Supply; Institutional and Cost Sharing Options, June 1973, would provide the various Connecticut reviewing agencies with information on what has already been done on this task. Copies of the reports were distributed earlier to the Connecticut State Coordinator's office.

I further feel that the recommendation for a supplemental analysis of legal/institutional implications may have been made without knowledge of the earlier Corps efforts in this field. I would be glad to discuss this matter with you at your convenience in the near future.

We concur with the consensus that no projects should be implemented without regard to downstream needs, plans and programs of downstream interests. As a matter of fact, in correspondence dated 11 March 1969 to Mr. Joseph N. Gill, the Corps requested such information from the State of Connecticut. Unfortunately no reply was ever received. As a result, the Corps of Engineers,

utilizing regional planning agency and unpublished state data, prepared estimates of future water supply needs and programs within Connecticut. This information, of course, was used in the plan formulation for the Northfield Mountain and Millers River reports.

The need for provision of a monitoring program is concurred in, and has been carried as a project element since an early date in the study.

In summary, I appreciate the time which you and your staff have expended in reviewing the Northfield Mountain and Millers River Basin reports. I feel, however, that some of the reviewing agencies' views on the projects under consideration were made without a historical perspective of all the NEWS studies which were conducted. A discussion of some of the above noted differences by members of your staff and my own may serve to aid in the resolution of these items. If you desire it, I would be pleased to have my staff meet with yours.

Sincerely yours,

JOHN WM. LESLIE
Chief, Engineering Division

CF:
Honorable Thomas J. Meskill
Governor of the State of Connecticut
State House
Hartford, Connecticut 06103

PRONOVOST

BERGEN

IGNAZIO

LESLIE

cc: Mrs. Quill
Mr. Leslie
Mr. Ignazio
Mr. Pronovost
Engr Div Files

STATE OF CONNECTICUT
DEPARTMENT OF FINANCE AND CONTROL
PLANNING AND BUDGETING DIVISION
340 CAPITOL AVENUE - HARTFORD, CONNECTICUT 06115

March 13, 1974

Mr. John WM. Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Thank you for your letter of February 1 in response to mine of January 2, which summarized the reactions of several state agency staffs participating in review of the draft study reports of the Northfield Mountain and Millers River diversions. I can fully appreciate the concern you express over certain aspects of this review and feel that an attempt at clarification may be in order.

The commentary relates solely to the review of the contents of the subject study reports and should not be interpreted as representing familiarity or criticism on the the part of reviewers with the background process of technical studies leading up to these particular reports. Any indication of shortcomings or inadequacies reflects the opinions of reviewers only as to the adequacy of these specific reports in providing a total and up-to-date presentation of all matters pertaining to these projects. It was within this context that there were felt to be inadequacies and imbalance in the consideration of alternative water supplies, cost/benefit analyses of alternatives and consideration of competing demands.

In reference to the matter of "costs" to Connecticut, I believe you have missed the main thrust of the concern of review agencies and I apologize for not stating it more clearly in recognition of our different perspectives. I can appreciate that your concern is with "cost" factors of the projects under immediate consideration. From the point of view of the review agencies representing the interests of the State of Connecticut, the major concern is one of longer range implications of cumulative interbasin transfers of Connecticut River waters. These could occur through future amendment to limitations on these projects which may be initially established or by the subsequent addition of similar projects which can be expected to result from the failure now to begin development of alternate sources of supply. The main point of concern is that these projects represent continued reliance for Metropolitan Boston water supply on diversion of Connecticut River waters t of the basin rather than on the development of more localized alternate sources with the result that over the long run we must anticipate incremental demands for further diversions of Connecticut River basin waters. It is this perspective of "costs" to Connecticut which review agencies urge be given consideration in the evaluation of costs related to these projects.

In reference to "legal/institutional mechanisms" for protecting interstate interests our basic concern is with the adequacy and clarity of presentation of the Corps of Engineers recommendations of such mechanisms. The concern expressed was that the reports under review did not set forth such recommendations. We are pleased to learn that your office has given high priority to investigation of the matter of legal/institutional mechanisms and would be interested in the type of recommendation you would make in this regard relative to the subject projects and the downstream interests, therein.

I appreciate the offer of availabilty of staff from your office to meet with staffs of the reviewing agencies as followup to the previous two meetings. Before exploring this further with those agencies, I would appreciate your advising me as to the schedule of activities or additional studies of your office, underway or anticipated, in relation to these particular projects. This would help considerably in evaluating the potential values to be expected from such meeting.

Sincerely,

Harold Ames
Director for Planning

cc: Gov. Meskill
IWRPB Members

HA:met

State of Vermont

AGENCY OF ENVIRONMENTAL CONSERVATION

MARTIN L. JOHNSON
Secretary

Montpelier, Vermont 05602

DEPARTMENT OF WATER RESOURCES

Department of Fish and Game
Department of Forests and Parks
Department of Water Resources
Environmental Board
Division of Environmental Protection
Division of Recreation
Division of Planning
Natural Resources Conservation Council

May 4, 1973

Mr. John W. Leslie
Chief, Engineering Division
Department of the Army, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

I have received the draft copies of the report entitled "Northfield Mountain Water Supply Project and Millers River Water Supply Project" and your letter requesting comments. We do not have the time nor budget to review these voluminous reports when they do not appear in any way to affect the State.

At the start of the N.E.W.S. study we had hoped some of the Vermont water supply needs and problems would be studied but it now appears that the urgent areas, four in number, will have major studies and the remaining areas may just have a superficial review.

We would be happy to review reports in future NEWS studies that in some way relate to Vermont. We would also ask that when and if such reports do relate to the State that it be pointed out to us to save tedious review of reports that have no bearing on the State's interest.

Sincerely yours,

John E. Cerutti
Acting Commissioner

JEC:mls

Citizens Review Committee
Millers River Diversion Plan
273 Bearsden Road
Athol, MA 01331

August 13, 1973

Mr. John W. Leslie
Chief Engineering Division
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Sir,

The following is the requested cooperative reply, to the Corps of Engineers Millers River Diversion Plan, from the Citizens Review Committee. In our conclusion we have attempted to be - open minded to the needs of both the receiving and the donor area - economically responsible as to the costs involved in the different alternatives and honest in our appraisal of the Corp's report and the three alternatives offered.

We believe that any plan to take water from a small tributary, such as the East Branch of Tully River, is economically unsound and would constitute an irresponsible action. The cost of 12 million dollars for the diversion of 8 million gallons per day (annual average) which by national average would satisfy the needs of approximently 50,000 persons,[1] is indefensible. To raise this amount of diverted water to 24 million gallons per day, which is the capacity of the aquaduct from Tully Dam to Millers River, would then raise more serious questions as to the effect

1 - Dr. Keshavan, Prof. of Hydrology - Worcester Polytechnic Institute served the committee as it's advisor.

on the remainder of the Tully Basin.

The fact remains that a more agressive and persistant utilization of present state powers should guarantee the completion of secondary and advance treatment facilities above the Millers River main stem diversion site before actual construction starts. This would certainly negate the need of a diversion from the East Branch Tully River and produce a savings of approximently 12 million dollars.

We recognize that the diversion of water from one river basin to another raises questions of riparian rights and therefore requires the need for state legislative action. We must respectfully insist that an adivsory group be established, made up of private citizens and responsible agencies, so that this recognized group may provide in-put to any legislative action. Positive statements should be included in this legislation pertaining to state involvement and responsibility. These should include but are not restricted to:

a) Financing of actual construction -
b) Insured flow maintenance -
c) Consideration of future water needs of the donor area -
d) An open-end clause allowing the donor area to go back to the Legislature should any unpredictable degradation of the Millers River Basin be caused by the Millers River Diversion Program.
e) Place the responsibility for an on-going water use study, for the Commonwealth.

We respectfully accept the study and alternatives offered as an important contribution to the solution to Massachusett water needs. The differences of opinions found in the conclusions are small but important.

In closing, we believe Alternative #1 - Millers River Only Diversion Plan - should be carried forward immediately into it's advance planning stage and that the financing responsibility should be sought from the necessary state and federal authorities.

In the Corps of Engineer's own words: "The Millers River Alternative offers recreation, water quality and flood control opportunities in addition to meeting the water supply needs. Some 30 miles of streams, from Winchendon to Athol on the Millers, and from Gardner to the confluence with the Millers on the Otter River, would become excellant quality water. The water quality of the Millers River below Athol would also be improved because of the reduction in pollutants upstream of Athol. The aesthetic value of the river and environs will be greatly increased."

Respectfully Submitted,

Robert L. Gray, Chairman

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The Commonwealth of Massachusetts
House of Representatives
State House, Boston

THOMAS G. SIMONS
ASSISTANT REPUBLICAN WHIP
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STATE HOUSE
BOSTON, MASS. 02103
(617) 727-2375

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August 15, 1973

Mr. John W. Leslie
Chief Engineering Division
United States Army Corps of Engineers
Trapelo Road
Waltham, Massachusetts

Dear Mr. Leslie:

I appreciate very much the opportunity to submit my comments on the draft study entitled "Northeastern United States Water Supply Study-Millers River Basin Water Supply Project" prepared by the United States Army Corps of Engineers.

As the Representative in the Massachusetts General Court from the Third Franklin District, a member of the Citizens Review Board, and a resident of the Millers River Basin Area, I am vitally concerned about the proposal to divert water from the Millers River Basin into the Quabbin Reservoir in order to meet the projected water needs of the Metropolitan District Commission.

At this time, I am not expressing an opinion on the question of whether <u>any</u> diversion from the MRB is necessary to meet the future water supply needs of the MDC. However, <u>assuming</u> that diversion from the MRB ultimately is determined to be necessary and feasible, I strongly urge the adoption of Alternative 1 (diversion from the Millers River only) over Alternative 2 (the Millers River and the East Branch of the Tully Brook complex) and Alternative 3 (the Tully Brook complex only). I believe that Alternative 1 best serves the total public interest as well as the interest of the people of the MDC communities and of the MRB communities.

The Corps of Engineers report recommends the selection of Alternative 2, the combined Millers-Tully option. The Corps report presents three reasons in support of its recommendation that water be diverted from both the Millers River and the Tully Brook.

First, the Corps report states that Alternative 2 will ensure a much-needed additional water supply of 24 million gallons per day (mgd) for the Quabbin Reservoir by 1980. At present, the average safe yield of the MDC system is about 305 mgd, while the current water demand on the system is 324 mgd. Diversion of the Connecticut River at Northfield Mountain, a project already approved by the Massachusetts Legislature and scheduled to become operational in 1976 (four years before any MRB diversion program is scheduled to begin) will add 72 mgd to the Quabbin and thereby fulfill projected water demands at least until 1984. Thus, the 24 mgd that might be diverted from the Tully Brook under Alternative 2 would not be necessary until after 1984.

Even if the Northfield diversion does not occur as scheduled, 68 mgd can be provided from the Millers River alone by 1980. There is no question concerning the capacity of the Millers to provide the full 68 mgd. The question is whether the Millers River will meet the water-quality standards of the Massachusetts Department of Public Health necessary for diversion at that time. These standards can be incorporated into the existing pollution-abatement program for the Millers River which already requires the installation of secondary waste treatment plants by that time. An accelerated program sufficiently funded and vigorously enforced by the state is required.

The key to any MRB diversion program is cleaning up the Millers River. It is true that today the DWPC pollution-abatement program for the MRB is behind schedule. Secondary waste treatment facilities at sixteen out of eighteen point sources of pollution in the MRB were supposed to have been completed by December 1972. As of July 1, 1973, only eight such facilities had been constructed. DWPC enforcement of water quality standards has been inadequate. The Millers River pollution-abatement program should be elevated in priority by the DWPC. The period between 1973 and 1980, the earliest time when diverted water will be needed, is more than sufficient time to make potable at least that portion of the Millers River above the intake of the aqueduct.

A successful MRB diversion program requires full cooperation between the DWPC and the DPH. The present lack of contact and cooperation between these two state agencies cannot continue if we are to achieve water quality levels in the Millers River sufficient to permit diversion. That amount of contact and cooperation must be increased tremendously.

Secondly, the Corps report cites the so-called "flexibility" of Alternative 2. The maximum potential yield of the Tully Brook is 24 mgd -- an extremely small quantity of water relative to the total projected future water needs of the MDC system and a small amount relative to the Northfield-MRB combined projects or even to the MRB project itself. This potential yield of 24 mgd would be reduced to 8 mgd when the Millers River is sufficiently clean to be diverted under Alternative 2, leaving a 16 million mgd unused capacity. The report states:

> The dual intake location afforded by Alternative 2 offers a large degree of flexibility in the operation phase. If, for example, a potential health hazard was detected in the Millers River, diversions could still continue from the Tully River.

That pollution abatement equipment on the Millers River, as on any other river, might malfunction is not inconceivable. However, any malfunctions undoubtedly would be infrequent, small in scale, and temporary. The initial construction cost of $9 million for this 16 mgd contingent or temporary supply of water is not justified. The "flexibility" provided by the Tully is a luxury item, the cost of which is exorbitant.

I suggest that all or part of this $9 million be used to accelerate the presently lagging Millers River pollution-abatement program. While priority should, of course, be given to installing treatment plants upstream from the acqueduct, available funds could also be used in pollution abatement efforts in the downstream area.

The "flexibility" of Alternative 2 will create a disincentive for the DWPC to ensure that the Millers River is cleaned up and that the treatment plants are maintained in good working condition. A delay in implementing the MRB pollution abatement program would threaten the attainment of the full yield, under any MRB diversion program, even under Alternative 2. It would also deny the people of the Millers River area the benefits of clean water which is legally and morally owed to them by the Commonwealth.

Thirdly, the Corps report asserts that diversion of the Tully is necessary to preserve the environmental quality of the Quabbin Reservoir. Here, the report again ignores the scheduled implementation of the Northfield project in 1976. The 72 mgd from the Northfield project will prevent a deterioration in environmental quality that would otherwise result from a diminition of the Quabbin's volume. And even if the Northfield diversion project is not ready by 1980, the water

quality of the Millers River -- with 84% to 90% BOD removal during low flow periods and, with the use of a skimming process, during high flow periods -- will be sufficient from a public-health standpoint for diversion.

The Corps report fails to substantiate any reasons for selecting Alternative 2 over Alternative 1. In addition, there are two very important arguments against any diversion from the Tully Brook.

First, the maximum yield of Alternative 2 is 76 mgd, which is only eight mgd more that the 68 mgd of Alternative 1. The costs of the Tully project under Alternative 2 are $9 million for construction and $0.5 million annually for operation. However, the Tully would function at 66% below its capacity. Thus, for each mgd taken from the Millers River, the average initial construction cost would be $0.53 million, while for each mgd taken from the Tully, the initial cost would be over $1.1 million. Furthermore, the average annual cost of operating the Millers section would be $0.044 million per mgd, compared to $0.06 per mgd for the Tully section. In essence, then, Alternative 1 is much more economically efficient than Alternative 2.

Second, a Tully diversion would have additional significant side effects. Diversion would eliminate the agricultural benefits from spring flooding on nearby farmland. Also, it would prevent spring canoeing, a popular sport, on these streams. One goal of any MRB diversion program is providing recreational facilities for the people of the donor area. There is little logic in adopting an alternative that eliminates an important existing recreational activity!

In conclusion, I believe that Alternative 1 -- diversion from the Millers River only -- is by far the best of the three alternatives under consideration. Alternative 1 will achieve the goals espoused by the Corp's report. Specifically, this alternative will:

1.) provide sufficient water necessary to meet the goals of the MRB diversion program;

2.) cost at least $9 million, and possibly a substantially larger amount, less than Alternative 2;

3.) ensure that the Millers River pollution-abatement program is implemented on schedule between 1973 and the date of diversion with the resulting benefits to the people of the Millers River area;

4.) make possible the use of the $9 million savings, or a part thereof, to accelerate or expand the Millers River pollution-abatement program;

5.) protect the fragile ecology of the Tully Brook from the potentially serious adverse effects of diversion and maintain the natural flows of other tributary streams of the Millers River and thereby protect their environmental quality; and

6.) preserve important existing economic and recreational uses of the Tully Brook.

I believe that any future planning should proceed in accordance with Alternative 1.

I would appreciate your response to the comments which I have made regarding the MRB diversion study.

Very truly yours,

Thomas G. Simons

Thomas G. Simons
Assistant Republican Whip

TGS/tav

NEDED-R 23 August 1973

Honorable Thomas G. Simons
Massachusetts House of Representatives
Room 448
State House
Boston, Massachusetts 02103

Dear Mr. Simons:

I am writing in response to your letter of 15 August 1973 to Mr. John W. Leslie, regarding the proposed Millers River Basin Water Supply Project.

I appreciate your thoughtful and thorough review of the Millers River Basin Water Supply Project report and your view that future planning should proceed in accordance with Alternative 1. I feel, however, that the position of the Massachusetts Water Resources Commission, adopted 13 August 1973, which recommends Alternative 2 as the candidate for future planning provides a more flexible approach. I have inclosed a copy of the Commission's letter to me describing their position.

As stated in the Commission's letter, further study on Alternative 2 will not delay or otherwise affect the planned improvements of the Millers River water quality. In addition, the letter recognizes that should water quality in the Millers River be improved to a degree suitable for water supply purposes, then 'only that portion of the diversion works running from the Millers River itself to Quabbin need be constructed, the utilization of the Tully River being rendered unnecessary.'

Use of Alternative 2 in future planning allows for a full consideration of the actual Millers River water quality prior to construction of any facilities. If the actual water quality in the Millers River at

that time is not of water supply quality, then the Tully increment could be used effectively. If, on the other hand, the actual Millers River quality was suitable for water supply purposes, then Alternative 1, which you favor, could proceed. Adoption of Alternative 2 for future planning purposes, therefore, does not preclude adoption of Alternative 1 if the Millers River water quality improves sufficiently.

Sincerely yours,

Incl
as stated

JOHN H. MASON
Colonel, Corps of Engineers
Division Engineer

cc: Mrs. Quill
Mr. Leslie
Mr. Ignazio
Mr. Pronovost
Engr Div Files

PRONOVOST

BERGEN

IGNAZIO

LESLIE

BURKE

MASON

The Commonwealth of Massachusetts
Department of Natural Resources
Leverett Saltonstall Building
100 Cambridge Street, Boston 02202

August 13, 1973

John H. Mason
Colonel, Corps of Engineers
Division Engineer
Department of the Army
New England Division,
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Colonel Mason:

Over the past three months the Massachusetts Water Resources Commission has examined the six-volume Northfield Mountain and Millers River Basin Water Supply Project reports, generated by the Northeast Water Supply Study. It is my pleasure to report concurrence on the following position statement regarding the study reports:

The Massachusetts Water Resources Commission has considered the draft Northeastern United States Water Supply Project: Northfield Mountain-Millers River Basin Projects submitted to us for review and comment. We find that your evaluation of the study area's current and future water supply needs is justified, realizing, of course, that trends may change, altering even the most carefully formulated projections. We also find that you have identified the major water supply sources which might reasonably be foreseen to be available within the time frames to be served. Environmental impacts have been adequately identified and evaluated within the constraints imposed by the imperfect knowledge of the more subtle ecological effects which might occur. We are pleased to accept the study and array of alternatives as a major water planning contribution, and a valued input to a state water plan.

We recommend that further detailed planning and implementation proceed, particularly with the Millers River Alternate 2 (two) proposal. Like the Northfield Project, the Millers River Basin proposal would involve diversions only during high flow periods. The General Court of Massachusetts has already authorized the Metropolitan District Commission to proceed with the Northfield project. The Tully-Millers Diversion Plan combines recreational use and a maximum level of pollution abatement with the water supply function. Diversion from the East Branch of the Tully River will afford a reasonable period of time to partially use the proposed tunnel from the Millers basin to Quabbin Reservoir -- during which time

the best elements of modern technology will be brought to bear to improve the water quality of the Millers River mainstem preparatory to its introduction to Quabbin. Diversion from the Tully will not delay or otherwise affect the planned improvements in the quality of Millers River water which will go forward pursuant to a fixed schedule. It is further conceivable that the needed improvements in the water quality of the Millers River might be achieved prior to the time that construction could be completed on the Tully-Millers scheme (Alternate 2). In that event, only that portion of the diversion works running from the Millers River, itself, to Quabbin, need be constructed, the utilization of the Tully River being rendered unnecessary.

The Commission is aware that full consideration is owed the donor area, and we commit ourselves to foster the legitimate local interests which have been expressed with both candor and dignity. We support the diversion from the Millers Basin as a part of a broader river basin plan which would be authorized concurrently with any future state enabling legislation regarding the diversion of flows from the Millers River Basin. The planning program would encompass, but not be limited to the following elements:

-- the possible creation of a permanent advisory river basin entity involving citizens and agencies in formulating plans and recommending management measures

-- a detailed mathematical modeling and water quality monitoring program to yield information needed to insure flow maintenance and to achieve a very high degree of pollution abatement -- at least to the level necessary for introduction of the Millers mainstem into Quabbin

-- the implementation of the state scenic rivers program on the mainstem and suitable tributaries

-- acquisition of additional land to complement existing open space lands now owned in the watershed for fisheries and wildlife, forestry and park purposes

-- a detailed delineation of areas which should be placed under a program of floodplain management

-- a detailed compilation of areas favorable for ground water development

-- a study to see if the utilization of state powers to preserve reservoir sites is needed for the protection of the donor area's future water supply options

-- a plan to provide access to high value outdoor recreation areas, especially those areas enhanced by the water pollution abatement program.

In summary, we foresee a state role in formulating a comprehensive plan for the Millers River Basin in which diversion, though a basic part, is but one aspect of water resource management to be implemented.

The Commission also acknowledges that its rightful role in the donee area is not limited to that of providing a water supply. Other water resource management functions here will include, but not be limited to, the following:

--continue studies to insure that opportunities to obtain yields from local sources, consistent with sound resource management, are fully utilized.

-- provide an educational program to emphasize the finite nature of our water resources, to discourage waste, and to coordinate this plan with water districts and departments

-- Make a continuing study of changing technologies which may make the use of saline and wastewater a viable alternative

-- obtain more detailed information on how water is currently distributed and used, to see if measures such as changes in pricing, dual supplies, industrial re-use, etc. can be feasible means of conserving high quality water, thus lessening the demand on Quabbin Reservoir.

Much of the foregoing can be accomplished with present state, regional and federal programs, though changes in priorities and additional funding would in some degree be required. However, like the NEWS study itself, the diversion projects are endeavors of major magnitude. Just as this very worthwhile study could only have been accomplished by the Congressional authorization of Federal participation in 1965, detailed planning and implementation can best be accomplished by the continuation of the effective State-Federal partnership achieved during the course of the study. We respectfully suggest that this report go forward to Congress with a request for continued Federal participation in a program of detailed planning and implementation.

The Massachusetts Water Resources Commission recognizes, and has identified in the foregoing, a strong state role in planning an overall basin program which is economically equitable, environmentally sensitive, and socially acceptable. Citizen participation has rightfully made us aware of our duty to maintain the basic integrity of river eco-systems and the economic self-interest of donor areas.

The Massachusetts Water Resources Commission understands that favorable Congressional action may establish funds for completing final engineering plans and defining institutional and cost-sharing arrangements. It is our further current belief that positive results of such a legislative program would be the actual construction of a water diversion tunnel from the Millers River Basin to Quabbin Reservoir by 1980.

Based on the foregoing assumptions, the Commission endorses the following implementation schedule:

By July 1, 1977, all point sources on the Millers River and its tributaries will be receiving the best practicable treatment available. This program will be administered by the Massachusetts Division of Water Pollution Control.

By 1979, advanced techniques of water treatment, if needed to produce water in the Millers River mainstem suitable for diversion to Quabbin Reservoir, will be developed and in operation under a Congressionally authorized cooperative federal-state program.

During the period from the completion of the required advanced waste treatment units in 1979, and prior to the completion of tunnel construction and diversion works, special studies of the actual quality of the restored Millers River will be conducted under the supervision of the Massachusetts Department of Public Health. Before actual diversion of the water from the Millers River mainstem is begun, the Department of Public Health shall be satisfied that adequate health safeguards are operative.

A strong input at the state level to achieve a comprehensive and equitable plan for the basin, coupled with the proven engineering ability of the Department of the Army's Corps of Engineers, will provide a practical means to complete two major vital elements to meet the long range water supply needs of the Northeastern United States. We support and recommend that additional Congressional authorization and funding be sought for the planning and implementation of the Northfield Mountain and Millers River Basin diversions.

Voted at the Regular meeting of the Massachusetts Water Resources Commission, August 13, 1973.

We appreciate the extended review period afforded us. During the past eight weeks, we have received additional inputs from Commission members and individuals. You may utilize this statement for appropriate purposes in connection with submissions to Congress regarding later phases of these important project proposals.

Sincerely yours,

Arthur W. Brownell, Chairman
Water Resources Commission

AWB/ehc/m

COMMONWEALTH OF MASSACHUSETTS

Franklin County

DEPARTMENT OF PLANNING

COURT HOUSE, GREENFIELD, MASS. 01301
773-3003

August 2, 1973

County Planner

Mr. John W. Leslie
Chief Engineering Division
U. S. Army Corps
Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

This agency has reviewed the Drafts of Northfield Mountain Water Supply Report and Millers River Basin Water Supply Reports dated March, 1973. Because these documents are part of a total proposal, review and comment are done on two levels. The first set of comments are specific notes pertaining to each diversion; the second set is a system.

NORTHFIELD DIVERSION

The basis of concern of this particular plan is the large amount of doubt and supposition upon which the conclusions are based. For example, the whole "first-cost" is based on the assumption that Connecticut River water will be assimilated by the Quabbin. The report, however, qualified the assumption by stating that a true prediction cannot be made. Constant monitoring will have to be done and a treatment plant, or other corrective action will have to be taken if problems occur. But, even in the fact of these doubts, the cost of the Northfield Project is affirmatively said to be the cheapest alternative. This type of reasoning appears questionable. It also appears to make all other conclusions suspect in that each alternative is rated on the 12¢ per 1000 gallon figure.

The report makes numerous statements that if the pollution abatement schedule is not adhered to (1976 implementation schedule) "the potential for increased pollution loads hindering the use of the river as a water supply source is a strong possibility" (P. 58 Northfield Mountain Water Supply Project, Vol. 1, Main Report). The lack of implementation further threatens the assumption that the Quabbin may be able to clean the imported water and, therefore, provide "free" water treatment. Present administrative action of not funding the water pollution control program at levels requested by Congress seems to indicate the 1976 deadlines will not be reached. We wonder what effect this has on the viability of the plan.

The matter of radiation keeps occurring. When the sampling was done for the report, it is believed that the Vernon Power Plant was not fully operational. Since that time the plant has attempted to become operational, but has been either shut down or restricted to partial operation because of a host of problems. Newspaper reports have stated that, on at least one occasion within the past two months the atomic plant's operation was stopped or reduced by the AEC because of excessive radioactive releases. Should not further sampling be done to be sure present radioactive loads in the river are not detrimental to inhabitants of the receiver area?

This agency has also noted numerous comments regarding diversion of the Connecticut River below 17,000 cubic feet per second. We would like to go on record that under no circumstances should that 17,000 cubic feet per second be lowered to accomplish additional diversion. The 17,000 cubic feet per second was legislated in an effort to protect the communities' interest on the Connecticut River. That number has been questioned by many agencies as to its relevance, as many feel 17,000 cubic feet per second is too low to maintain a sound river ecosystem. The question and resulting indecision on this number makes us feel that at this time it should be held "pat" until further definition of the relevancy of that number is determined. We call it to your attention that the gauging station for the c.f.s. includes the flow of the Deerfield River and is not the flow at the Turners Falls dam. Therefore, water is being added to the Connecticut from a river system that could bear no function in the Millers diversion.

MILLERS RIVER PROGRAM

As indicated by the Corps, Alternative Number Two appears to be the most appropriate. From the receiver area's point of view, this is surely quite true. The plan, if implemented, will allow the Tully portion to be developed first. The "carrot" for the donor area in this case is the hope of a cleaned up Millers mainstem, or at least a portion of it. The problem arises by the fact that there appears to be no guarantee that the Millers will be cleaned. It seems highly probable that, once Tully is developed, further studies may say that the Millers is of too poor quality for economical clean-up and that portion will be abandoned. Admittedly this is speculation, but this agency feels it would be more appropriate to either take Alternative One (Millers River only) or build firm guarantees into Alternative Two (Tully-Millers) that the Millers will be cleaned up, if any diversion is to be done.

GENERAL COMMENTS

The most outstanding piece of data in both reports is the mention of the Sudbury River Basin and Reservoirs. The report discounts this alternative quite easily without explaining why the cost of developing the system is twice as expensive as the recommended projects.

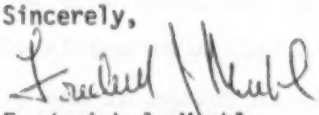
It further appears that the recreationist is being given a greater weight in the Sudbury area than in western Massachusetts. The report leads us to believe that one of the considerations (cost) not to use the Sudbury is the fact that it is now "recreation" water. On the other hand, it is noted that there is no mention of opening the Quabbin for more recreation. Does this mean water in the east is more important for recreation than drinking? On such a value scale, what, then, is water worth to people in western Massachusetts? You seem to imply that it is less.

Remaining with the Sudbury, both reports indicate that the Sudbury was once a water supply system and in 1947 the Massachusetts legislature (presumably with MDC approval) abandoned it. As a result of poor judgment, you are now asking an area, that will receive essentially no benefits, to take the brunt of the lack of judgment by supplying its resources to ameliorate that mistake. Is this fair?

The proposed projects seem to violate a recent court case involving a noted air pollution decision in the so-called "Four Corners" area of Utah, Colorado, New Mexico and Arizona. In that case the judge indicated that air quality which was presently "excellent" could not be lowered, even though federal minimum air pollution standards would not be exceeded. An analogous situation concerning the Four Corners decision seems to be occurring here. Based on data supplied by the Corps it appears that the Quabbin Reservoir will still remain suitable for drinking purposes. However, in this case, through the process of diversion, according to the same Corps data, some degradation of the Quabbin can reasonably be expected. Is this a violation of the precedent set in the Four Corners case? In this era of environmental awareness, it is proper to degrade a natural resource when other options (possibly most costly) appear to be open? Would not the environmental movement be strengthened by upgrading the Sudbury? On a larger scale would the three "accounts" be better served by spending precious time and money in revitalizing the existing water system through some of the alternatives brushed aside in the report? We feel these items should be given a <u>full</u> and fair analysis before proceeding with vast resource transfers between individual ecosystems, the Connecticut River Basin and eastern Massachusetts.

In summary, it is our belief that the program and plan, as presented by the Corps, does not adequately ameliorate a serious need in the receiver area. It is a short-term solution that treats only the needs and concerns of the receiver area at great expense to the donor area. The real issue, water concervation and use, is not discussed and solutions to that issue are not drafted. The approach outlined in the Millers River Basin Water Supply Project and the Northfield Mountain Water Supply Project leads us to ask one further, but fundamental question; What area is scheduled next for diversion?

Sincerely,



Frederick J. Muehl
Planning Director

South Road
Templeton, Mass. 01468
August 15, 1973

Dept of the Army - New England Division
Mr. John Wm. Leslie - Chief Engineer
424 Trapelo Road
Waltham, Mass. 02154

Dear Mr. Leslie:

My comments to the Millers River Diversion Project are as follows:

This report is full of half truths, assumptions, miss representation of facts and guess work. I have spent much time studying this report and after completing it find there are many inconsistent statements. There is not one positive statement about anything except that out of 28 purposed sources of additional water the only one that is perfect is the Millers River Basin Diversion Project. That in itself is enough to make anyone doubt the whole thing.

The M.D.C. stated at a meeting in Boston, and I quote, " We want the water from the Millers River Basin and we are going to take it." That shows the attitude of the M.D.C. With this thought in mind the study was made of this area. I am sure there are just as many problems and faults with the Millers River Basin Project as with any of the other 28 alternatives but by a strange coincident there is not one disadvantage mentioned. Either to the donor or receiver areas. How come this perfect area of water supply has existed for so long a period without someone using it before? It is absolutely asinine to think along this line.

I spent some little time at the desalting plant in Key West, Florida, and found out that everything you have said about it was absolutely false. The superintendent of the plant used to live in Lowell, Massachusetts and is familiar with this area and is of the opinion that a desalting plant could be built in Boston at the present time.

. . . This Millers River Project is not of that magnitude but is just as important to us. You take one item at a time and analyze it and say the adverse effect will not be enough to cause any problems, but if you take the combined adverse effects of all the items put together the result could be all most as catastrophic to this area as the one in Egypt was to them.

My personal feelings, and there are some facts to back them up, are that the only practical and logical solution to the water problem is a desalting plant, or several, in the Boston area. They will have to use water from the ocean eventually so why put it off? Spend the money now for a sensible project, and be done with it, instead of throwing it away on a temporary solution and causing a lot of hard feelings and misery in this area.

There is one thing that bothers me a great deal about the M.D.C. Why won't they talk about a desalting plant? Every time desalization is mentioned they immediately change the subject or give you false information about it.

At a three day convention at the University of Massachusetts last year a gentlemen started to speak about the possibility of a desalting plant in Boston, he had made a study of it, and he was told in just so many words that we were there to discuss the diversion plans, not a desalting plant. This man picked up his material and left the convention. Before anyone could talk to him. This happened just before the lunch break. When we reconvened after lunch a new moderator apologized for the actions of the previous moderator and stated that we were interested in all phases of water supply and if the gentlemen wanted to speak about desalization he could have the floor. It was too late he had gone home. Nobody knew what he was going to say but I am sure it was along the same line that I have discussed. The M.D.C. just does not want to even think about anything else except the Millers River Basin Project. If you mention waste water and using it for drinking purposes you get the same reaction.

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The cost of a desalting plant would not be as much as the combined cost of the alternatives that are mentioned in the report and it would be a project that would give unlimited water for as long as it was needed. It would not upset the entire area of Massachusetts in the process either. The Millers River Basin Project, by your own statement, will only supply you until 1990. It will also spoil a large section of the last natural recreational area in this part of the state.

To say you will clean up the Millers River in return for some of the water is, also, a missleading statement. I have worked with the town officials and engineers in this area and by law they are going to have to abate any effluent from being discharged into the river. There will be more treatment plants built in the near future and the river will be cleaned up by ourselves. After wehave cleaned it up why should we give it to an outsider? We can and will develope our own recreational facilities to meet our needs as desired and will not be under the dictates of some power 60 miles away. If the good Lord had wanted the water from the Millers River Basin to run to Boston I am sure he would have diverted it there himself.

You people claim that you have made a study of this area and have found that no adverse repercussions would occur t o the donor area.

This brings to mind the Assuan Dam in Egypt. The best engineers in the world made a study of that area and came up with the same conclusions that you people have. The adverse effect of this project would be minimal to the area. The damage to the social, economic and environmental status of the whole country is beyond belief. There are whole sections that will never be the same again. The life patterns of thousands of people have been ruined. Many square miles of land have been rendered useless because they are no longer flooded during the wet season. The marine life has become extinct in some areas and so will the people that depended on it. They realize they made a mistake in changing the natural flow of the river but what can they do about it now?

Fairmont, West Va. has been using waste water out of the Monongahela River for 35 years. I know because I was there and toured the plant in 1948. The water in the Monongahela River looks and smells worse then the Otter River in Templeton, Massachusetts does now. This water was pumped to a treatment plant and processed. I don't know what it cost but nobody was complaining about it. The water was like fresh spring water when it came out of the tap. The City of Fairmont was about as large as Fitchburg, Massachusetts is now and this was their only source of water. The thought of using waste water for drinking just makes the M.D.C. shudder and their comment is, "Impossible."

There has got to be a change in the thinking about what type of water is to be used for drinking purposes sooner or later and it might just as well come now.

I shall expect a reply and an answer to the questions as put forth in this letter as well as the questions regarding the report in the other letter.

Thank you for your time and consideration in this matter. I am on the radio now and then and I would like to have some concrete facts that I can give to the radio audience.

Very truly yours,

Duane R. Leonard

Duane R. Leonard

South Road
Templeton, Mass.
August 15, 1973

Dept. of the Army - NewEngland Division
Mr. John Wm. Leslie, Chief Engineer
424 Trapelo Road
Waltham, Mass. 02154

Dear Mr. Leslie:

Thank you for sending me a copy of the technical sections of the draft reports on the Millers River Water Supply Project.

Listed below are my comments regarding the report.

Page XXII Para. 2 ✓ 85 communities imposed restrictions on water use.

Page XXXI Para. 4 ✓ 50 communities imposed restrictions on water use. Why the difference.

Page XXXIV Para. 4 ✓ What about the loss to the donor area?

Para. 5 ✓ This paragraph gives the best description of what will happen to the donor area if this diversion is implimented.

Page XXXV Para. 2 ✓ What happens to farms located in the cloud seeding areas if it rains all the time?

Page XXXVI Para. 1 ✓ Water costs 75 cents per 1000 gallons in Templeton now and this is not from desalinization.

Page XXXVI Para. 2 This paragraph is entirely false. There is no concentrated brine effluent. There are no waste products such as soot, heat, smoke, toxic gasses, etc. There is no increase in temperature of the brine and no copper content.

Para. 3 There is no reason why desalinization cannot be used in Boston at the present time.

Page XXXIX Para. 2 ✓ How many wells in this 1000 to 1500 acres?

Para. 3 ✓ How would you get the water to the people from the Millers River if no pipes were laid?

Para. 6 ✓ Who says so?

Page XL Para. 5 This is just an assumption on your part.

Page XL	Para. 5	This would be a one time expense only.
Page XLIII	Para. 2	Who is not metered?
Page XLIV	Para. 1	Why didn't you have test areas in the area that is effected? What good is a test area in some other section of the country?
Page XLV	Para. 2	Why not find out?
	Para. 4	It would be better to have a few restrictions then to upset several towns for the sake of giving unlimited water to the M.D.C.
Page XLVII	Para. 1	Why not get the facts before making a report?
	Para. 2	There is no basis for this statement. You are guessing.
	Para. 4	How can you make a decision on the millers river project without making an effort to find out about water saving devices?
	Para. 5	Why hasen't the water supply industry advocated water conservation?
Page XLVIII	Para. 3	Why Not?
	Para. 5	What does this mean?
PageL	Para. 1	So you don't bother with it.
	Para. 4	So you don't bother with this one either.
Page LIII	Para. 5	Who decided no action on the alternatives?
	Para. 6	What about future needs?
Page LIV	Para. 3	What about the long range?
	Para. 5	Why not find out?
Page LV	Para. 2	How do you know?
	Para. 3	Why aren't these studies made to give you some concrete facts before guessing at the results?
Page 14	Para. 3	How do you arrive at this conclusion?
Page 22	Para. 2	What is SMMA?
Page 24	Para. 1	What is the reason for your projected decline?

Page 58	Para. 4	According to your way of thinking the Millers River economic area can wither and die because Boston needs water.
Page 59	Para. 4	Why would there be no storage for water supply within the flood control reservoir?
Page 62	Para. 1	Could take water anytime during the year.
Page 68	Para. 2	How big would the pool be?
	Para. 2	It was stated at a previous meeting that the area had to be cleared.
Page 70	Para. 2	Stated on page 68 paragraph 2 that it might be cleared This paragraph says it will be cleared. Which is it?
Page 71	Para. 1	Told us at Orange it would take ten years to construct.
Pages 72 & 73		What does the figure of $123,000.00 for major replacement include.
Page 82	Para. 1	Why not?
Page 88	Para.	No information to date on the impact of the diversion on the donor area. There is nothing specific. Just generalities and these are only guessing.
Page 98	Para. 3	You say that the impact on the donor area will not be great enough in most areas to effect anybody and then you state in this paragraph that there is no way to figure the impact after 1990 because of a lack of information. How do you arrive at this decision except by guessing.
Page 106	Para.2	How about new industry moving into the area?
Page 107	Para. 4	What will be the total restrictions?
	Para. 5	This tells it just like it will be.
Page 109	Para. 3	According to you it is inthinkable to have low water in the Quabbin because of odors and exposure to unsightly bottom areas but this conditioncan exist for 9 months out of the year in the Priest Brook and Tarbell Areas. What kind of thinking justifies this?

Page 109	Para. 4	How could payments made in lieu of taxes be counted as savings?
Page 125	Para. 2	Industry will not locate in an area where the water is limited and that is what will happen to the donor area.
	Para. 3	There is no logical reason why industry and the M.D.C. should not have to pay for water treatment just because, up to this point, it had not been necessary.
Page 127	Para. 3	There are social impacts in the donor area that are just as important as the ones in the receiver area.
Page 128	Para. 3	Why not use the word assumed instead of postulated? That is what it means.
	Para.4	If the minimum control flow is 17,000 cfs why are you using the figure of 12,000 cfs?
Page 129	Para. 5	You are only guessing regarding change in time and location of shad spawning.
Page 130	Para. 2	Here again you admit you don't know enough about the situation but state there will be no problems. How can you do this?
	Para. 3	Guessing again.
	Para. 4	How can you make a definite statement when you admit you don't know?
Page 131	Sect. b	Why do you still use the figure of 12,000cfs if you don't intend to go that far?
	Sect. c	You don't know.
Page 132	Para. 2	1% of the average annual run off would be an incorrect per cent. what would the percent be for 2½ or 3 months taking the annual amount of water?
Page 133	Para. 1	Guessing again.
	Para. 4	You stated that a 2% change in temperature would cause many changes on page 130 yet you say here that

a 4.3% change would have no significant effect.

Page 136 Para. 5 There would be no flushing action on the river after the diversion so the sediment in the bottom of the river would remain there.

Page 137 Para. 1 ✓ Where do you get your facts for this assumption.

Para. 2 ✓ This would have an effect on the water table.

Para. 3 ✓ If there is sifficient water going over a dam the fish will also go over the dam.

Page 138 Sect. 2 ✓ This area is one of the most used areas of the river for canoe racing so how can you say there would be limited impacts?

Page 139 Para 1 ✓ You will have approximately 15 acres of bare ground for 9 months of the year.

Page 141 Para. 4 ✓ How do you justify this inundation of 40 acres of wetland with regard to the wetland protection Act Chapter 131 Section 40?

Page 142 Para 1 ✓ What about the impact on this area?

Page 142 Para. 2 ✓ Here again we have 400 acres of mud and sand for 9 months. The impact on this area would be extreme.

Para. 6 ✓ Another large area of mud and sand.

Page 144 Para. 4 ✓ Cofrer dams could be used but will they? We have several areas that have been ruined by silting when construction was going on.

Page 148 Paral ✓ Is the K.D.C. going to give the 2.8 million dollars back to the towns that had to pay more then that to clean up the water so the K.D.C. could use it or are they going to pocket it?

Page 149 Para. 3 ✓ Why is there such a large range of cubic yardage of rock spoil?

Page 151 Para. 2 The main concern of the K.D.C. is the revenue they will lose if the diversion is not implimented. The

loss to the donor area is far more important than money.

Page 154 Para. 6 ✓ There is no guarantee that the millers river will ever be fit for the Quabbin so why speculate on it?

Page 156 Para 2 If the millers river can never be used the cost of the amount of water from the rest of the area will be prohibitive.

Page 157 Para. 1 This project would not give the amount of water needed.

Page 160 Para. 3 Let the areas with plenty of water benefit from new industry. Don't kill a potential industrial area by giving the water to an area that is already crowded.

Para. 5 ✓ How can you figure losses on something you don't have?

Page 161 Para. 3 If another source of water or a conservation program was instituted they would not have to take as much water from the Quabbin and it would remain healthy.

Para. 4 To impliment the diversion would not offer a realistic solution to the donor area.

Page 165 Sect. 24 ✓ This whole section is falsely presented. There is not one statement or fact that is true. I made a tour of the plant in Key West, Florida, in May, 1973.

The cost of 1000 gallons of water is 84.5 instead of $1.00 as stated.

There are no hazards to the enviroment.

There is no concentrated brine effluent.

There are no waste products such as soot, heat, smoke, toxic gasses, etc.

There are no concentrations of Chloride or Copper.

There are no adverse effects on marine life.

There is no build up of dry salt deposits.

The plant covers about 1 acre and produces 2.6 million gallons of pure water per day.

The total plant cost 4 million dollars. This is a

a long way from 49 million dollars for the millers river diversion. There is no reason why a plant of th type cannot be used now in the Boston area, except that the M.D.C. don't want to.

Page 169 Para 3 You could do a.lot of experimenting and build quite a desalting plant to supply an unlimited amount of wate for many years for 8½ billion dollars. This would not ruin the rest of the natural recreation areas left in the New England Area.

Page 172 Para. 1 Fairmont, West Va. has been using waste water for drinking purposes for 35 years. The M.D.C. just don't like the idea so they reject the alternative.

Para. 3 Simply because the M.D.C. don't want to use it.

Page 175 Para. 4 What will the cost be to find a new source of water after the millers river basin has been exploited?

Page 176 Para. 3 This is just an assumption on your part.

Page 180 Para. 1 When will this study be completed?

Page 189 Para. 4 Is any work being done and if so when will it be completed?

Para. 6 This does not make any sense at all. It is better to have some restrictions then not to have any water.

Very truly yours.

Duane R. Leonard
Chairman Templeton Commission
Member of S.C.S.
Member Citizens Review Board
Treasurer and Director of the
Millers River Watershed Council

Mr. Randall/je/511

NEDED-R 10 September 1973

Mr. Duane R. Leonard
South Road
Templeton, Massachusetts 01468

Dear Mr. Leonard:

This is in response to your letter of 13 August 1973 commenting on the Millers River Basin Water Supply Project.

Inclosed are a number of articles on desalinization and waste water reuse for your consideration. Also inclosed are comments on the specific questions you raised concerning the technical points of the Millers River Basin Water Supply Project Report. I hope these responses will clarify our work.

Sincerely yours,

Incl
as stated

JOHN WM. LESLIE
Chief, Engineering Division

cc: Mr. Leslie
Mr. Ignazio
Mr. Pronovost
Engr Div Files

RANDALL
PRONOVOST
BERGEN
IGNAZIO
LESLIE

The following are comments on the points you raised concerning the technical sections of the Millers River Basin Water Supply Project Report:

Page XXII, Para. 2 - The reference to 50 communities imposing restrictions was a typographical error. 85 is the correct number.

Page XXXIV, Para. 4 - In the supply area, the major impact of the no-action alternative as stated in the report would be the probable deterioration of Quabbin Reservoir.

Page XXXV, Para. 2 - Cloud seeding is still an inexact science. Predictions of amounts, duration and location of rainfall produced cannot be made with absolute assurance. Therefore, weather modification does not appear to be a reasonable solution to the immediate water supply problem.

Page XXXVI, Para. 1 - The costs for desalinization quoted in the report are only for the plant construction and operating costs, not for the transmission of the water from the plant to the consumer. To this cost you should add the various distribution costs such as new tunnel or pipes and the water department's operating expense.

Page XXXIX, Para. 2 - There would be approximately 120 wells in this 1000 to 1500 acre area.

Page XXXIX, Para. 3 - As explained in the report, water would be diverted from the East Branch Tully River and the Millers River by deep rock tunnel to Quabbin Reservoir and through existing transmission facilities to the consumer. Therefore, the only surface disruption would be at the two or three shaft locations.

Page XXXIX, Para. 6 - This is based on our analysis of the costs and impacts of a large groundwater development in the Plymouth County area.

Page XLIII, Para. 2 - The member communities served by the MDC in 1965 reported that they had 347,989 metered service connections out of a total of 362,237. Most of these unmetered connections occur within the cities of Boston, Cambridge and Peabody.

Page XLIV, Para. 1 thru XLVIII, Para. 5 - As part of the recommended actions, we will be doing further investigations to determine the possible long range effects of various demand conservation measures including pricing, restrictions, water-saving devices and education programs.

Page LIII, Para. 5 - As stated, no-action is one of the alternatives investigated.

Page LIII, Para. 6 - This evaluation included estimates of future needs
Page LIV, Para. 3 and still only minimal impacts are expected.

Page LIV, Para. 5 - As stated on page LIV, concurrent investigations
Page LV, Para. 3 on water demand and its make-up would be done.

Page 14, Para. 3 - Our geologists researched and investigated the area.

Page 22, Para. 2 - SMSA is a Standard Metropolitan Statistical Area.

Page 24, Para. 1 - The basis for projected economic growth is given in Appendix A.

Page 59, Para. 4 - No storage in the East Branch Tully Reservoir is required in Alternative No. 2 - Tully-Millers Diversion because the eight-foot diameter tunnel can handle the diversion flows from the watershed without storage.

Page 62, Para. 1 - Water would be diverted only when the flow in the rivers exceed the established required flow and then only the amount in excess of that flow.

Page 68, Para. 2 - We assume the question refers to the waterfowl pool on Priest Brook. The size of this pool as described on Page 64 and shown on Plate No. 18 would be 40 acres.

Page 68, Para. 2 - The reference to clearing and stripping on Page 68 is
Page 70, Para. 2 referring to the waterfowl pool area on Priest Brook. As described earlier on Page 64, the remaining area downstream of Royalston Road would have to be stripped or covered with a gravel blanket. In developing cost estimates for the project, as described on Page 70, it was considered conservative to estimate costs based on the entire area being stripped.

Page 71, Para. 1 - As described at the Public Meeting, it would be about 10 years before any water could be actually diverted from the Millers River Basin. Following completion of the report, it would be forwarded for review by higher authorities. If approved by higher authorities, the report would be presented to Congress. If authorized by Congress, the project's final design plans and specifications would be prepared. Finally, construction of the facilities (estimated to take 3 years alone) would be accomplished. The entire process then would require about 10 years.

Pages 72 and 73 - Please refer to Page 71 which explains what is included in the major replacement costs.

Page 82 - Don't understand the question.

Page 98 - Baseline projections are not available on a town by town basis through 2020. However, they are available on a regional basis. The assumptions referred to in the text are of disaggregating the regional projections to town level. Therefore, when discussing the impacts after 1990, we are talking on a regional basis rather than a local basis.

Page 106 - Because the required control flows do not permit diversions to reduce the flow in the Millers River below what normally occurs in the summer months, it is safe to conclude that the diversions will not jeopardize the location of new industry in the area. Also, the availability of water is not, in most cases, one of the prime reasons for the location of an industrial plant.

Page 107 - If any restrictions are placed, they would only apply to the watershed upstream of the diversion. In any case, restrictions would be made only after a thorough analysis of the specific circumstances by the Massachusetts Department of Public Health.

Page 109, Para. 3 - This is one of the reasons why Alternative No. 2 - Tully-Millers Diversion was recommended; i.e., because it does not involve Priest or Tarbell Brooks.

Page 109, Para. 4 - What is being said is that if the payments in lieu of taxes are more than the taxes now collected, then the difference between these payments and the taxes can be counted as "savings" under the "no-action" alternative; i.e., no project being constructed.

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Page 128, Para. 3 - This question appears to be a case of semantics. Our intent is using the word postulated was to insure that the reader did not infer that all diversion flow rates and control flows were under active consideration. As stated, the full range investigated was intended to allow a full investigation of any potential impacts.

Page 128, Para. 4 - As it states in that paragraph, we are not using a figure of 12,000 cfs as the control flow for the alternatives. We only investigated the effects of maintaining a 12,000 cfs control flow in order to allow for a full investigation of all the options.

Page 130, Para. 2-4 - Our investigations used a wide range of diversion flow rates and control flows. The reason for adopting this range was the belief that if the larger diversion rates (4000 cfs) and lower control flow (i.e. 12,000 cfs) indicated limited impacts, then lower diversion rates and higher control flows would be expected to have even less impact. This, in fact, is what the results of the study concluded.

Page 131 - See response to question, page 128, para. 4.

Page 132 - Since about 50% of average runoff in central and northern New England occurs during springtime, the value would be about 2% of the flow during this period.

Page 133, Para. 4 - On Page 129, Para. 3, we stated that a 2°F change, not a 2 percent (%) change, in temperature would result in no significant changes in the estuary. The 4.3% change is the maximum change in temperature on the mainstem Connecticut River due to diversion.

Page 137, Para. 1 - See Appendix I.

Page 137, Para. 2 - No significant impact would occur based on discussions with U. S. Geological Survey.

Page 137, Para. 3 - Subject paragraph is referring to free movement of fish in the stream.

Page 138, Para. 1 - Impacts described are based on the A.M.C. New England Canoeing Guide assessment of this river reach.

Page 139, Para. 1 - This alternative would not change the situation along the river because the majority of the 15 acres is in the existing river bed.

Page 141, Para. 4 - Although this alternative was not selected, investigations were conducted for the impacts which development would have on public or private water supply, to ground water supply, to flood control, to storm damage prevention, to prevention of pollution, and to the protection of fisheries. In no case was any significant impact identified.

Page 142, Para. 1 to 6 - Impacts are described on pages 143 to 145.

Page 144, Para. 4 - Coffer dams would be used if necessary.

Page 148, Para. 1 - The figure referenced is additional treatment costs in eastern Massachusetts which would be borne by the MDC. The costs for additional waste treatment plants in the Millers River Basin to insure water supply quality has always been carried as a project cost. It has never been suggested or stated that local Millers Basin communities would be required to furnish any treatment above that required by law.

Page 149, Para. 3 - Range given is for the three alternatives.

Page 154, Para. 6 - As stated, the problem is not that the Millers River will never be acceptable, but that it may not be available when needed.

Page 160, Para. 5 - In Stoughton, these losses were from planned housing and industrial development which were going to be occupied until the water shortage.

Page 165, Section 34 - Although a statement, not a question, we have attached information on desalination for your use. It should also be noted that the Key West plant produces only 2.6 million gallons per day at 4 million dollars. The Tully-Millers plan on the other hand would produce 76 million gallons per day at 44.8 million dollars. On just a pro rated basis, it is obvious that desalting is expensive.

Page 172, Para. 1 - This comment is a statement rather than a question; however, information on waste water reuse has been attached.

Page 175, Para. 4 - Information on future alternatives is included in the summary and main report.

Page 180, Para. 1 - This study is being conducted by the MDC. Further information should be obtained from that agency.

Page 189, Para. 4 - As stated on page 198, investigations on water demand and its make-up will be done in conjunction with the implementation of the Millers River Project, if it is implemented.

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From: Final Report to the President and Congress of the United States by the National Water Commission, JUNE 1973

Chapter 9

Means of Increasing Water Supply

In the past, studies of water supply have been directed almost exclusively at controlling and distributing the existing streamflow or ground water supply to increase its utility and make it available to serve the growing demands for water in a particular region. In some areas, however, control of the existing supply has been pushed to or near the physical limit and pressures are building for works to transfer water from one river basin to another. Perhaps in recognition of these pressures and in the belief that there may be alternatives which could delay or eliminate the necessity for such transfers, the National Water Commission Act specifically directs the National Water Commission to consider alternative ways of meeting future water requirements, including those which might come about through technical advances.

In compliance with its legislative mandate, the Commission undertook two types of studies. The first was a detailed state-of-the-art examination of three specific possible means of increasing water supply for which research and development is fairly well advanced. These are desalting, precipitation augmentation, and land management. These three technologies are discussed in detail in the next three sections of this chapter. The second was an overview of potential future technological advances including those which would have the effect of increasing water supply. The results of the overview analysis dealing with potential means of increasing water supply are presented in Section E of this chapter.

INCREASING WATER SUPPLY BY DESALTING[1]

Sea water, which has a concentration of 35,000 parts per million (p.p.m.) of dissolved solids, and brackish water, which contains much less dissolved solids than sea water but which still is too concentrated for drinking or irrigation, are found in or near many places where fresh water supplies are limited but in great demand. Until recently, however, it was not technically feasible to convert meaningful amounts of sea water or brackish water into fresh water. But some 20 years of research and development, largely financed by the Federal Government, has greatly changed that picture. Today, the technology for large-scale desalting is at hand. What remains unsolved, however, at least in many areas of potential application, is economic feasibility.

In view of the investment which has been made in desalting research and development and of the obligation to consider alternative means of meeting future water requirements, the Commission has sought to ascertain to what extent in the future the Nation will be able to depend upon desalting as a source of water supply.

To appraise the likely future role of desalting, the Commission arranged for a state-of-the-art analysis. The analysis was directed toward appraising how close the Nation is to financially feasible desalting, considering present costs and possibilities for future cost reductions, the probable future markets for desalted water in view of the indicated costs of production; and the effect of noneconomic problems associated with desalting, such as adverse environmental impact. Finally, desalting was weighed in a general way against the alternative means of increasing water supplies.

State of the Art[2]

After 20 years of research, the mechanics of the most important desalting processes are reasonably

[1] This section is based largely on KOELZER, Victor A (1972). Desalting, prepared for the National Water Commission. National Technical Information Service, Springfield, Va. Accession No. PB 209 942.

Multistage flash distillation plant at Freeport, Texas

[2] This section includes information taken from U.S. OFFICE OF SALINE WATER (1971). Desalting Plants Inventory Report No. 3. Office of Saline Water, Washington, D.C., and O'MEARA JW (February 4, 1972). Statement of J.W. O'Meara, Director, Office of Saline Water, U.S. Department of the Interior, before the House Subcommittee on Irrigation and Reclamation. Mimeo. Office of Saline Water, Washington, D.C.

well understood. Worldwide use of desalting in small-sized plants in selected situations is fairly extensive. But the capacity of desalting plants is expanding rapidly, at a rate of 18 percent per year for the 10-year period 1961-1971. In 1970, 33 plants were placed in operation throughout the world, with a combined capacity of 59.7 million gallons per day (m.g.d.) and an average capacity of 1.8 m.g.d. The existing installations in the world, as of January 1, 1971, were as follows:

Process	No. of Plants[a]	World Plant Capacity (m.g.d.)	Percent of World Capacity
Distillation	688	290.4	95.5
Crystallization	3	0.3	0.1
Membrane	54	13.6	4.4
Total	745	304.3	100.0

[a]Of these, 64 had a capacity of 1 m.g.d. or more.

The U.S. and its territories had a total of 321 plants each having a capacity of 25,000 gallons per day (g.p.d.) or more, with a total combined capability of 54.8 m.g.d. The largest plant in operation anywhere in the world has a capacity of 30 m.g.d. It is the plant in Kuwait which began operating in 1972. A plant of this size is sufficient to supply municipal and industrial water for a population of 150,000 (assuming water requirements of 200 gallons per capita per day). The next largest is a 7.65 m.g.d. plant located at Terneuzen, Netherlands. A contract has been awarded for a 48 m.g.d. distillation plant in Hong Kong. The largest desalting plant in the U.S. is located in Key West, Florida. It has a capacity of 2.6 m.g.d. A sea water distillation module capable of producing 3 m.g.d. is now under construction in California's Orange County. Since January 1971, the estimated additional capacity placed in operation or under contract would increase the world total to about 440 m.g.d. Of this total, 14 m.g.d. is by the electrodialysis process, 12 m.g.d. is by reverse osmosis, and the rest is by distillation.[3]

Plants outside the U.S. are located primarily in the Middle East (Kuwait, Israel, and Saudi Arabia), the Caribbean, Latin America, and Europe (Netherlands, Spain, and the USSR). Much of present and future installed capacity is or will be sited outside the U.S.

[3]Data based on communication with the U.S. Office of Saline Water, Washington, D.C. (October 1972).

A variety of processes are used in desalting.[4] As indicated above, distillation processes furnish most (nearly 95 percent) of the existing world capacity. About two-thirds of the capacity of the distillation plants use the multistage flash (MSF) process. However, about half of the distillation plants (mostly smaller plants representing only a small fraction of total capacity) utilize the now obsolete submerged-tube distillation process.

Currently, distillation is used almost exclusively for desalting sea water. Membrane processes, on the other hand, are used only for desalting brackish water, although recent research has indicated promise for application of the membrane process to desalting sea water as well. Crystallization processes, primarily freezing, probably are limited to small plants of 5 m.g.d. or less.

Extensive study has been made of dual-purpose plants (in which heat is used both for power generation and for desalting). The conceptual technology of dual-purpose nuclear plants has had considerable attention and appears to be sound. However, the only dual-purpose plants that have been built—a 2.5 m.g.d. plant at St. Thomas in the Virgin Islands, a 5 m.g.d. plant at Jidda, Saudi Arabia,[5] and the 7.5 m.g.d. plant at Rosarito Beach (Tijuana), Mexico[6]—are not large enough to demonstrate large-plant feasibility.

Costs of Desalting

Desalting costs have been significantly reduced in recent years. In 1952, when the U.S. Office of Saline Water (OSW) was established, the costs of desalting water in a few land-based plants ranged upward from $7 per 1,000 gallons in terms of current dollars.[7] Costs have now been reduced to about $1.00 per 1,000 gallons in sea water conversion plants and about 50 cents per 1,000 gallons in brackish water plants. Costs quoted for desalted water usually are at

[4]Descriptions of desalting processes are included in a report by the Office of Saline Water. See U.S. OFFICE OF SALINE WATER (1968). The A-B-Seas of Desalting. U.S. Government Printing Office, Washington, D.C.

[5]U.S. OFFICE OF SALINE WATER (1972). Saline Water Conversion Summary Report, 1971-1972. U.S. Government Printing Office, Washington, D.C. p. 5.

[6]U.S. OFFICE OF SALINE WATER (1970). Desalting Plants Inventory Report No. 3. U.S. Government Printing Office, Washington, D.C. p. 11.

[7]U.S. OFFICE OF SALINE WATER (1972). Saline Water Conversion Summary Report 1971-1972. U.S. Government Printing Office, Washington, D.C. p. 1.

the plant boundary. Since most plants are at or near sea level, additional costs may be necessary for pumping to the plant of use. At present, long-range projected desalting costs are on the order of 25-35 cents per 1,000 gallons at the plant (based on 1972 dollars) for large sea water desalting plants and less for brackish water plants.[8] The considerable spread between present costs and this goal emphasizes the fact that economic feasibility of desalting for many applications has not yet been proven and that efforts to reduce costs relative to alternative sources must be continued if desalting is to become a significant source of water supply. Many of the low prices that have been quoted for future desalting assume low interest rates, dual-purpose technology, large plants, and/or negligible brine disposal costs. The rapidly rising cost of energy will be a severely negative influence in achieving reductions in the cost of desalting.

Possibilities for Cost Reduction

Through Improved Desalting Technology: Advancements in desalting technology will take place, but unless and until a basic breakthrough occurs, totally unforeseen today, they are apt to be limited to gradual design improvements. The development of a longer-lived and more effective membrane for reverse osmosis particularly seems to offer the prospect of a large reduction in costs. Recent progress on the reverse osmosis process for both brackish and sea water applications has been highly encouraging.[9]

Through Reduction in Cost of Energy: While the energy requirements of the various processes differ rather widely, all desalting techniques require relatively large quantities of energy. With the exception of solar processes (which are not highly promising for installations of appreciable size), this energy must be supplied either by steam or by electricity. Among other factors, the minimum energy requirement depends on the salinity of the water to be treated. Lower salinity waters—up to 10,000 p.p.m.—are amenable to desalting with one of the membrane processes. Reverse osmosis and electrodialysis may be operated at very low energy consumption by operating at low pressure on the one hand or low current density on the other. Such operation, however, would sacrifice plant output and thus would involve a tradeoff of capital investment (the desalting facility) for low energy consumption.

Higher salinity waters—10,000 to 50,000 p.p.m.—can be desalted by one of the distillation processes. Tradeoff of capital investment for low energy consumption is also possible. That is, high efficiency plants—the Clair Engle demonstration plant at Chula Vista, California, for example—require heavy capital investment for construction of additional heat recovery stages. Energy usage at this plant is about 40 times the theoretical minimum (2.65 kw.-hr. per 1,000 gallons). Thus, if the energy rate is 5 mills per kw.-hr. the energy costs alone would still be about 13 cents per 1,000 gallons, or $43 per acre-foot. To this, of course, must be added the annual debt service on the capital cost of the desalting plant, as well as operating and maintenance costs, which together presently represent about 50 percent of production costs in most plants.

The implications of high energy use and resultant cost are evident. (The relationship between cost and demand for desalting is suggested in the subsequent discussion of markets for desalting.) They have caused desalting scientists to focus as much or more attention on the reduction of energy costs as on the basic desalting processes. There are only two ways in which energy costs can be reduced: (1) by reducing the cost of obtaining energy or (2) by more efficient use of the energy, for example, by combining power generation with desalting.

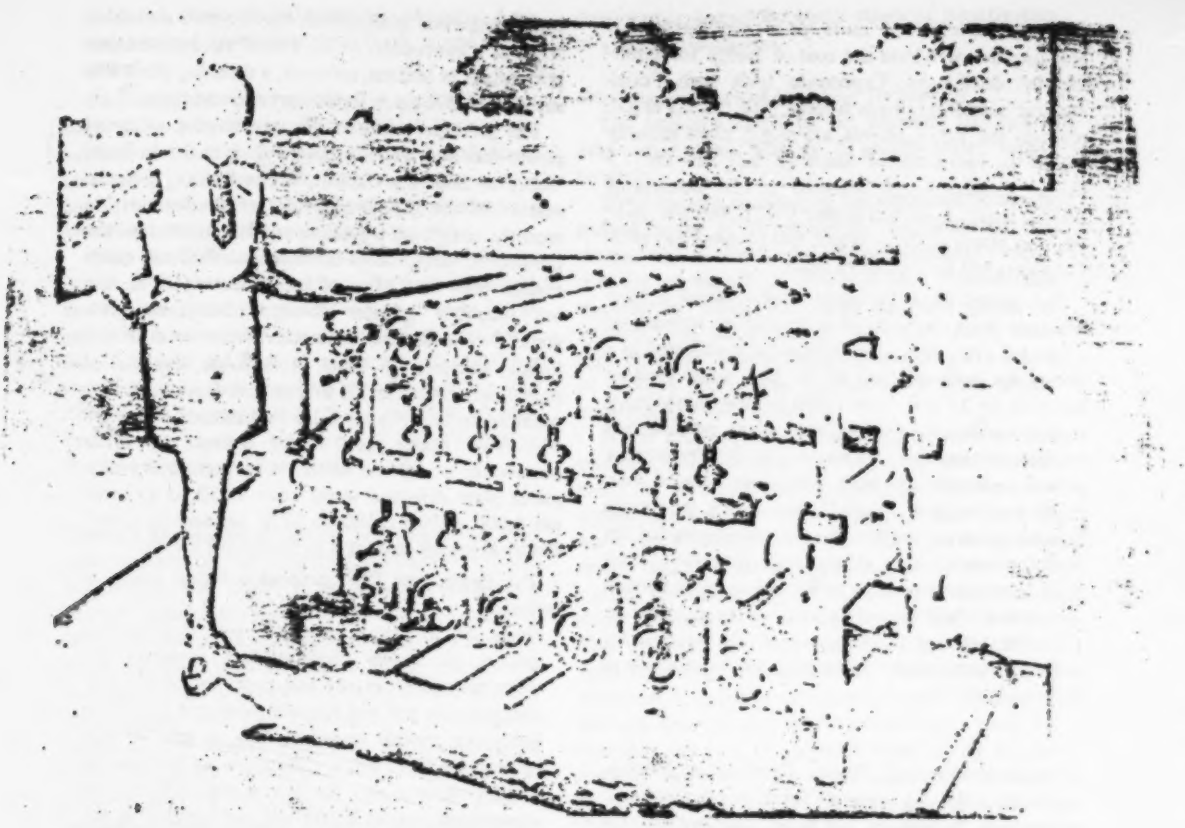
One potential means of reducing the cost of obtaining energy is by reducing the cost of producing steam for distillation or of power for other processes. The power industry appears to have already taken advantage of most of the possible economies of scale. With the rapid increase in fossil fuel cost, the industry is moving rapidly toward nuclear fueled plants for which projected steam costs are expected to remain relatively stable and lower than from fossil sources. A principal relatively near-term hope for reducing the cost of energy (steam or electricity) is in the use of breeder reactors in nuclear powerplants. Some experts forecast that, by the year 2000, the breeder reactor will produce energy at about 60 percent of present costs.[10] Others, however, suggest that such reductions involve consistently optimistic assumptions.[11]

[8] *Ibid.*, p. 45.

[9] Informal advice from OSW based upon recent laboratory results with sea water.

[10] STATE OF CALIFORNIA, Department of Water Resources (1969). Desalting—State of the Art, State of California Bulletin No. 134-69. State of California, Sacramento. p. 26.

[11] CLAWSON M et al (June 6, 1969). Desalted water for agriculture; Is it economic? Science 164:1141-1148.



This reverse osmosis unit produces 27,000 gallons of high-quality water per day from brackish sources

Another possibility for reducing energy costs is to operate desalting plants on offpeak energy. A plant could operate under a contract for interruptible power with the power utility having the right to drop the load of the plant when an emergency occurs which requires use of reserves. For some desalting processes it would even appear possible to substitute a carefully controlled load-shedding system for spinning reserve, thereby effecting further economies in the cost of energy. This does not necessarily require that the plant operate only at nights or on weekends. Indeed, a desalting plant served by interruptible power might in some circumstances operate nearly 100 percent of the time. Similarly, dual-purpose power production-distillation plants may be operated on a basis of partially interruptible steam to take advantage of low-cost steam which might be available on this basis. It must be appreciated that desalting plants operating on an interruptible basis cannot be relied upon as a firm water supply unless adequately backed up by storage or an alternative source.

Under such operation it should be possible to obtain energy at essentially the cost of fuel. This implies an energy charge but no capacity charge. However, because this kind of desalting operation would use plant facilities which are normally held in reserve, and because the economics of power system operation usually places the older and less efficient, as well as less pollution-free, plants in the reserve and peaking operation positions, desalting on an interruptible energy basis would more often than not involve, directly or indirectly, use of higher-cost plants.

Through More Efficient Use of Energy: The potential for using part of the heat from a nuclear or fossil fueled power generating plant for desalting

probably represents a more promising method of reducing the near-term net cost of energy for desalting by distillation. Experience with such "dual-purpose" desalting plants is limited to the 2.5 m.g.d. plant in the Virgin Islands, a 5 m.g.d. plant recently placed in operation in Saudi Arabia, and the 7.5 m.g.d. installation at Rosarito Beach. Conceptual designs have been developed for large-scale dual-purpose plants at Roba Island and Diablo Canyon in California and for a plant in Israel.

The proposed dual-purpose Roba Island Project was not built because of a significant increase in estimated cost. While this increase was reflected in a rise in the indicated cost of the fresh water product from 22 to 37 cents per 1,000 gallons, the primary reason for not proceeding with plant construction was the increase in costs associated with the nuclear power production facilities which experienced even higher percentage increases.[12] Apparently, the Diablo Canyon desalting project was not recommended for early construction as a large-scale prototype plant because of indicated water costs and required Federal investment. Still large-scale, dual-purpose plants in the 50 to 100 m.g.d. capacity range offer promise for reducing costs and the technology for them needs to be developed.

Through Geothermal Plants: Geothermal development represents a special form of dual-purpose technology. By utilizing hot brine generated by heat beneath the earth's surface, both a water supply and power production can be obtained. Desalting of the brine, of course, is required if it is to be a source of water supply. However, because the source usually is at high temperatures (varying from 150° to 700°F.), the external energy that must be introduced is low. When the pressurized brine is tapped by a deep well, it flashes into a mixture of steam and hot saline water that flows to the surface.

Power generation using geothermal energy is feasible by itself in certain circumstances.[13] There are currently 728,000 kilowatts of installed geothermal power capacity in the world, half of it in Italy. Most such geothermal powerplants do not produce usable water as a byproduct. At the Cerro Prieto geothermal powerplant in Mexico, however, a desalting plant also supplies 38,000 g.p.d. for construction workers.[14]

The principal potential for combined geothermal power-desalting plants in the U.S. is in the Imperial Valley of Southern California. The Bureau of Reclamation of the U.S. Department of the Interior has recently completed a preliminary investigation of the geothermal potential of the Imperial Valley in cooperation with the Office of Saline Water (OSW), and has proposed a more detailed investigative program.[15] The Bureau estimates that a total of 1.1 billion acre-feet of brine is available, capable of providing as much as 2.5 million acre-feet of desalted water annually. To prevent land subsidence, the water withdrawn would need to be replaced by other wastewater or by sea water. Very preliminary estimates place delivered water costs at 30 to 45 cents per 1,000 gallons ($100 to $150 per acre-foot) and electrical energy costs at 3 to 5 mills per kw.-hr.

The Bureau and OSW propose a 3-stage study, as follows:

Stage 1: A 7-year research and development period, to obtain physical data necessary for determining the extent and potential of the geothermal resource and to build pilot and prototype plants to provide operating data. A total of $16 million for the 7 years is indicated to be required. (As a prelude to this, the Bureau and OSW are now cooperating on an 8,000-foot well drilled in the Imperial Valley in 1972. Well construction is by the Bureau, with OSW providing and operating a portable desalting plant.)[16]

Stage 2: A demonstration of large-scale development, to provide 100,000 acre-feet of desalted water annually and 400-500 megawatts of power. Replacement fluids would be from the Salton Sea, the Wellton-Mohawk Drain, or from ground water.

Stage 3: The program would provide for delivering up to 2.5 million acre-feet of water annually and

[13] STATE OF CALIFORNIA, Department of Water Resources (1969). Desalting–State of the Art, State of California Bulletin No. 134-69. State of California, Sacramento. pp. 41-43.

[13] STATE OF CALIFORNIA, Department of Water Resources (1970). Water for California–The California Water Plan Outlook in 1970, State of California Bulletin No. 160-70. State of California, Sacramento. pp. 88-91.

[14] ANONYMOUS (May 6, 1971). Geothermal resources gather a head of steam. Engineering News-Record 186(18):30-35.

[15] U.S. BUREAU OF RECLAMATION (1972). Geothermal Resource Investigations, Imperial Valley, California; Developmental Concepts, Bureau of Reclamation, Office of Saline Water, Washington, D.C. pp. iii, 55.

[16] U.S. BUREAU OF RECLAMATION (February 1972). Reclamation Report Cites Water, Power Potential in Geothermal Development, News Release 4523-72. U.S. Department of the Interior, Washington, D.C.

producing about 10,000 megawatts of power. A sea water source for replacement fluids would be required.

Obviously, this is a long-range program. The first stage alone would span 7 years. The Commission believes that the geothermal potential is well worth investigating, at least to the point where valid comparisons can be made with other alternatives for providing additional water supply to the area.

While the Commission has no basis for judging the details of the proposed program, it endorses the need, the objectives, and the general outline of stage 1. The question is raised, however, as to whether stages 2 and 3 should be Federal programs; no overriding requirement is seen for such a determination. The Commission suggests that the possibility of non-Federal development be given full consideration at the time stages 2 and 3 are undertaken.

Through Economies of Scale: Desalting plants offer some opportunity for reduction in unit costs through increases in size. There is an economic breakpoint beyond which the cost of incremental capacity becomes approximately constant. This is about 100 m.g.d. for distillation and about 10 m.g.d. for reverse osmosis. On the other hand, conventional sources of water supply, which are alternatives to desalting and which do not involve significant energy inputs, do offer substantial opportunities for economies of scale—a dam, a reservoir, a pipeline, or even a treatment plant usually become significantly less expensive per unit for supply as its size is increased. At the same time, many projects for conventional water supply will involve long-distance transfers, substantial investment for capacity not immediately required, and significant environmental and social questions; thus, they involve other kinds of costs.

Through Staged Construction: There are advantages accruing to desalting, derived from its flexibility to adapt to stage construction. Since desalting plants can be built in modules, they can be scheduled to meet increases in uses, as such uses grow. Conventional water supply sources usually require investment in large single increments of capacity, often resulting in unused capacity for many years. Such unused capacity is costly, because interest and other fixed costs must be paid whether capacity is fully utilized or not. Even more important, perhaps, are the smaller incremental requirements for capital investments associated with desalting and the better cash flow to meet debt service during the initial stages of amortization of a capital investment.

Other Applications of Desalting Technology

The potential exists to use desalting facilities in roles other than that of a purely water supply function.

These include desalting of contaminated surface or ground water or of wastewater and industrial discharges high in dissolved solids and relatively undesirable for municipal or industrial uses. Considerable opportunity exists for using desalting plants to improve such water supplies. With increasingly stringent discharge criteria, the use of desalting as a means of meeting clean water standards will likely attract more attention in the future.

Where other sources of high quality water are not available, desalted water can be mixed with brackish water for municipal and industrial use. In effect, this augments the usable water supply. Thus, if brackish water has a salinity content of 1,000 p.p.m. and the usable quality limit is considered to be about 500 p.p.m., the usable volume of desalted water can, in effect, be doubled by blending it with brackish water. This approach has been considered in a number of areas including California, Utah, South Dakota, and elsewhere. It could be applicable wherever a supply of brackish water is economically available. In Utah, for example, the cost of a blended water supply by this method, delivered to the municipality, was estimated to vary from 19 cents to 33 cents per 1,000 gallons ($63 to $108 per acre-foot), depending upon the desalting process used and the source of the feed and blending water.[17]

Reuse of treated wastewater will be of increasing importance in the future. Where mineral buildup through reuse is a problem it may be desirable to utilize desalting for its removal. While in any instance chemical precipitation or dilution with high-quality water may be attractive alternatives, the potential for desalting in connection with wastewater reuse could be significant. This potential has had very little attention in the research investigations of the saline water program but now is receiving increasing attention. It may become an area of early major application for desalting.

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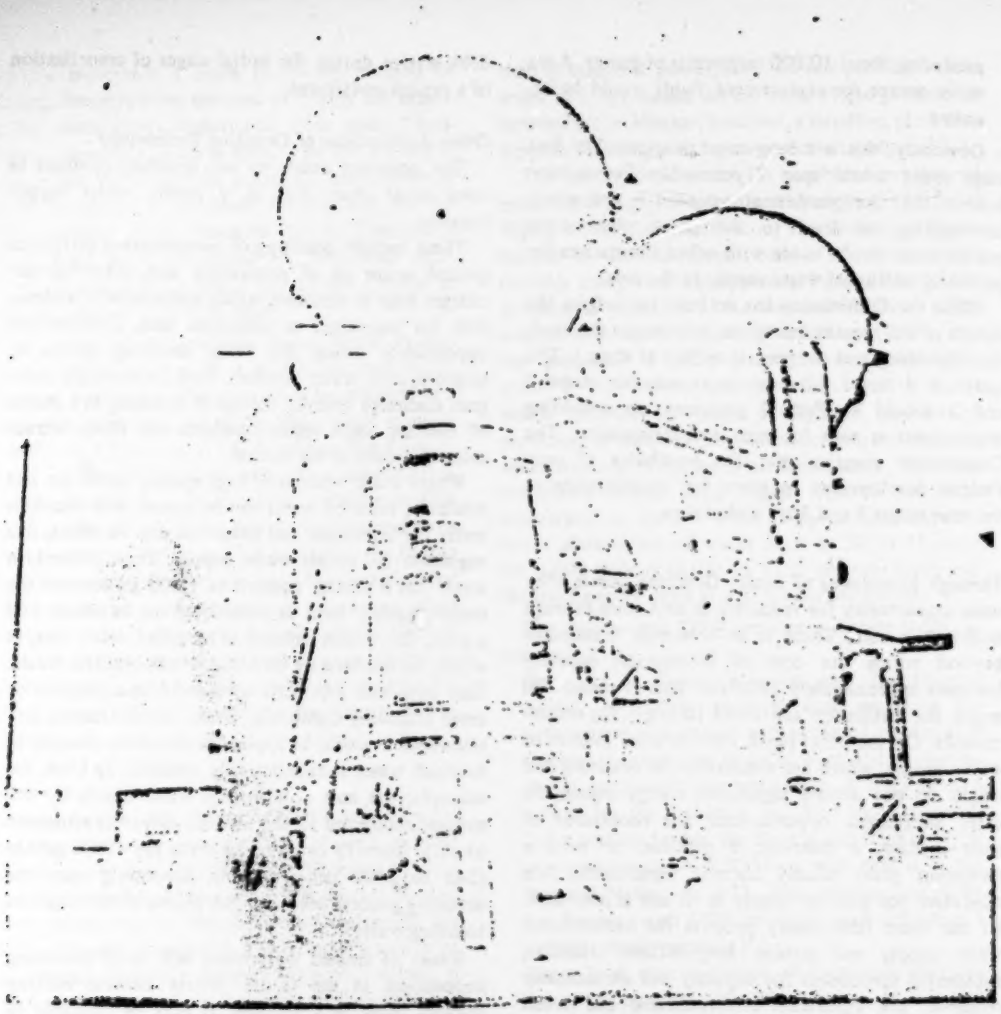
[17] HAYCOCK, Edwin B. et al. (1968). Utah Desalting Study, Preliminary Assessment of Desalting and Electric Power and Process Steam Production for the Wasatch Front Area. Utah Department of Natural Resources, U.S. Office of Saline Water, and U.S. Atomic Energy Commission, Salt Lake City, Utah. pp. 7, 149.



Forced circulation vapor-compression plant at Roswell, New Mexico

Desalting may be used as a means of treating point-source of some kinds of pollution. For example, the Office of Saline Water and the Bureau of Reclamation have undertaken a program for the control of salinity in the Colorado River. Under this program detailed attention is given to the potential for using desalting to control pollution by dissolved solids from mineralized ground water or other point-sources and from irrigation return flow.

Desalting and conventional water supply systems may be operated conjunctively. Under this approach, with an abundance of feed water, a desalting plant would be operated on an intermittent or interim basis to supplement natural or regulated surface supplies. The ability of a desalting plant to be operated as needed makes it adaptable to such a function. It would be used during seasonal peaks, periods of drought, or when the capacity of reservoirs or other water supply facilities had been reached, because of expanding requirements, but before additional facilities were constructed. In effect, this would stretch conventional water supplies and their associated facilities. The economics of this approach do not seem to have been thoroughly explored. However,

conventional water supply sources have a much higher ratio of fixed capital costs to variable operational costs—on the order of 75 percent capital cost to 25 percent variable operational cost—compared with a corresponding ratio of about 40 percent to 60 percent for desalting plants. This might give desalting some advantage over conventional sources as an intermittent source of supply because the significantly smaller capital investment in facilities used only periodically may result in lower unit costs for the standby capacity. However, capital cost per unit of production will often be higher for desalting than for conventional sources of supply, particularly when ground water is a possible alternative. The use of desalting as a water supply source, in any instance, should be reviewed in terms of its impact upon the total water system economics as compared to alternative sources meeting the same needs.

Environmental Problems

Disposal of waste products from desalting plants can be a difficult problem under some circumstances. The volume of brine effluent from a sea water conversion plant typically is about 50 percent of the total volume treated. The effluent from a 10 m.g.d. plant will contain about 2,000 tons of salt residue daily. Where discharge can be made to the sea, disposal problems will be relatively minor, but the impact on the local ecology will still need to be investigated. Where disposal is inland, the problem will be much greater. Possible inland disposal methods include evaporation ponds, transport by conduit to the ocean or other salt water body, deep well injection, or central stockpiling of dry salts. Each disposal method has disadvantages, some from the viewpoint of costs, others from the viewpoint of possible environmental effects. The market for most of the salts is limited, so recovery and disposal through sale will not be practical in most instances.

Desalting plants can add to local environmental problems by discharge of waste heat from (a) producing the additional power necessary to desalt and (b) the heat in the plant effluent when a distillation process is used. While these heat discharges could be significant locally, they would represent small values in national totals. Significantly less heat will be discharged when power production and desalting are combined into a single dual-purpose plant.[18]

[18] STATE OF CALIFORNIA, Department of Water Resources (1969). Desalting—State of the Art, State of California Bulletin No. 134-69, State of California, Sacramento, p. 33.

Probable Markets for Desalting

The future market for desalting will depend upon the interaction of a number of factors. Costs of production to be attained in the future will be significant as will the costs of any potential alternative. But other factors such as institutional and social considerations also will be important. In 1971, the Office of Saline Water analyzed in a preliminary way the potential market by the year 2020 for desalting under different assumptions regarding population growth, availability of alternative sources of water supply, water quality requirements, the degree of water recycling, and other factors.[19] That study indicated a wide range in the potential for desalting depending upon the particular set of assumptions. For example, a baseline projection of 7.7 b.g.d. was found if future water demands are about equal to the projections of the First National Assessment, discussed in Chapter 1, and if technology continues to improve and costs continue to decline. On the other hand, if costs were to remain constant at present levels and alternative water sources were available, the desalting demand would be relatively small at 1.1 b.g.d. If no further water importation projects were permitted, the study suggested a desalting demand of 40 b.g.d. A number of other projections keyed to different possible factors fell within these two extremes.

The study also indicated that the demand for desalting is highly sensitive to cost differences. The tabulation below based upon operating a 100 m.g.d. plant, with costs adjusted to a 1972 level, indicates the effect of different costs on the demand for desalting.[20]

Assumed desalting costs in 2020 (cents per 1,000 gallons)	Desalting capacity justified in 2020 (b.g.d.)
42	2.5
36	4.1
30	7.8
24	15.7
16.6	31.8

As indicated earlier, these cost figures, especially at the lower end of the spectrum, may have to assume

[19] U.S. OFFICE OF SALINE WATER (June 24, 1971). Briefing Session for the Desalting Industry, U.S. Department of the Interior, Washington, D.C.

[20] *Ibid.*, p. 21.

low interest rates or other favorable conditions in order to be achieved.

Markets for Municipal Use: Much of the future market will be for small- and medium-sized plants, up to 10 m.g.d., to serve small communities, industries, and remote developments in arid areas. Applications may develop, as well, for medium-sized plants, of 10 to 50 m.g.d., as increments to the water supply for medium or large cities. In special situations, costs could be competitive.

Still larger plants in the 50 to 250 m.g.d. range could serve the needs of large cities or regional municipal supply systems. Costs may be competitive with alternative sources of water in arid areas near the coast, such as Southern California, or in areas of brackish water, such as Utah. However, extending known technology to this size of plant, probably involving dual-purpose operations, is a step into the unknown.

Desalting may serve not only as a means of supplying water for municipal and industrial uses, but also for improving the quality of existing supplies. Moreover, some 1,200 communities in the United States currently have water rates to the consumer in excess of 75 cents per 1,000 gallons for the first 10,000 gallons used per month.[21] Future costs of conventional water supplies for these and other communities will certainly be higher than present costs. The increasing concerns about the effects water development will have upon the environment, institutional constraints, and competition from other types of water use all will add to the difficulty of developing conventional water sources in the future. Desalting may have application in areas having these types of problems even prior to the time that costs are reduced and desalted water becomes more nearly competitive with that from other sources.

Markets for Irrigation Use: The forecasts of water cost for plants in the large 50 to 260 m.g.d. size range, using existing technology ($80 to $180 per acre-foot), would seem to rule out irrigation use of desalted water when compared strictly on a cost-per-acre-foot basis. However, studies have demonstrated that this kind of comparison is not altogether valid—the utility of an acre-foot of desalted water (which is more or less pure) cannot be equated to that of an acre-foot of natural water (which usually contains some salt).[22] If water of very good quality such as that obtainable by distillation were used for irrigation, water use could be limited essentially to that required for the plant's growth. With such water, a high level of management could be combined with the most modern agricultural technology and specialized plants to create a very productive agriculture. This potential probably will not be realized at present desalting costs.

There appears to be a limited opportunity for growing specialized crops in enclosed environment systems with desalted water.[23] A multipurpose experimental plant at Puerto Penasco, Baja California, in Mexico has been sponsored jointly by the Universities of Sonora and Arizona. The plant combines a 2,400 g.p.d. power-desalting plant with air-inflated plastic greenhouses to grow vegetables under controlled environment conditions. Since water evaporated or transpired by the plants is not lost to the atmosphere and there are no other water losses, consumptive use is about one-tenth of that common in field irrigation. A 5-acre plant of this type is now in commercial operation in the Shiekdom of Abu Dhabi, in the Middle East. A similar 5-acre commercial plant is now under construction on an Indian reservation near Yuma, Arizona.

Other technological innovations, on much larger scales, have been investigated in more theoretical terms. Of particular interest is a large-scale agro-industrial combination grouped around nuclear energy centers studied by the U.S. Atomic Energy Commission's Oak Ridge National Laboratory and by Texas A&M. This complex would provide electric energy and desalted water, and process steam and raw materials for a variety of industries. It also would provide desalted water for irrigation.

There are many questions to be answered before desalting for irrigation use occurs; certainly, significant irrigation use is not justified with present or immediately foreseen technology. Nevertheless, it is too early to write off the possibility of future

[21] AMERICAN CITY MAGAZINE, Pittsfield, Mass. (1971). Nationwide Study of High Municipal Water Rates, Research and Development Progress Report No. 719, prepared for U.S. Office of Saline Water. U.S. Government Printing Office, Washington, D.C. p. 4.

[22] U.S. OFFICE OF SALINE WATER (1969). Value of Desalted Water for Irrigation, Research and Development Progress Report No. 489, U.S. Government Printing Office, Washington, D.C.

[23] HODGES, Carl N & HODGE, Carle O (1969). Power, Water and Food for Desert Coasts: An Integrated System for Providing Them. Paper presented at 66th Annual Meeting, American Society for Horticultural Science, Pullman, Washington.

irrigation use for specialized crops and situations. It should be recognized, however, that even very limited use for irrigation would represent a large desalting investment—about 10,000 irrigated acres alone would require the entire present 55 m.g.d. desalting capacity of the U.S. At half the delivery requirement of Colorado River water, costs of desalted water using existing nuclear technology would still be equivalent to $40 to $90 per acre-foot, greatly in excess of the $2 to $10 per acre-foot average price of irrigation water (which usually includes substantial subsidies) and even in excess of the estimate value added by irrigation of specialized crops in Arizona, computed as being $27 to $36 per acre-foot.[24]

Application of Desalting Technology

Desalting plants capable of contributing significantly to a resolution of metropolitan area or regional water problems must be substantially larger than any operating today. While research and laboratory tests on desalting processes and pilot plants are important steps in research and development, a final step, the prototype stage, also is important to prove and demonstrate a major new technology such as desalting. The Saline Water Conversion Act of 1971[25] authorized and directed the Secretary of the Interior to report to the President and Congress within 1 year his recommendations as to the best opportunity for the early construction of a prototype desalting plant. The Act defines prototype as, ". . . a full size, first-of-a-kind production plant used for the development, study, and demonstration of full-sized technology, plant operation, and process economics."

While the Secretary, in response to that directive, reported in 1972 that a desalting plant site meeting all of the requirements had not been satisfactorily identified, the need remains for prototype experience.

It appears highly likely that solutions to the inevitable problems that accompany scaleup in plant size can only be obtained in reasonable time with Federal assistance. In addition to questions related to plant design, purchasing, managing, and operating desalting plants involve considerations needing attention. Early answers to questions about the actual cost of such plants are important to the Federal Government if it is to judiciously appraise the costs, the environmental and social impacts, and the suitability of desalting as an alternative to other large-scale water development projects (such as interbasin transfers of water) that involve Federal funding. The Atomic Energy Commission characterized the role of a prototype desalting plant as being similar to that of the Shippingport nuclear power generating plant of the 1950's which demonstrated the practicability of such plants and which was supported by Federal funds.[26]

Hence, the Commission believes that the Federal Government should provide assistance in the construction of a large prototype desalting plant for research and development purposes. To the extent that other entities secure benefits from such a research and development effort, they should be obliged to share in its costs to the equivalent of what they would otherwise have had to pay for the benefits they receive.

Large desalting plants will be constructed of individual desalting modules or units having a capacity of perhaps 20 to 40 m.g.d. each for plants using the distillation process. Membrane processes, on the other hand, do not require as large a unit module size. Units of 10,000 to 100,000 g.p.d. capacities using the reverse osmosis process can be added in modular fashion to make up plants of over 100 m.g.d. total capacity. From a purely technical viewpoint, while a single module would provide adequate data on the problems involved in scaleup from the smaller pilot plants, such a single module could not demonstrate all of the problems or take advantage of the opportunities encountered in a full-size plant operation. As indicated earlier, for example, the least cost of production for a distillation plant will be reached at about 100 m.g.d. Moreover, a prototype plant should be designed for and capable of helping to meet an existing water problem which could require a plant capable of a dependable output.

Depending on the circumstances, then, it may be appropriate for the prototype plant to consist of two or more modules. This matter will need to be weighed when the particular prototype plant is under consideration.

[24] NATIONAL ACADEMY OF SCIENCES (1968). Water and Choice in the Colorado Basin. A Report by the Committee on Water of the National Research Council. Publication 1689. NAS, Washington, D.C.

[25] P.L. 92-60, July 29, 1971, 85 Stat. 159, 42 USCA 1959 *et seq.*

[26] U.S. CONGRESS, Senate, Committee on Interior and Insular Affairs (1971). Saline Water Conversion Program, Hearings before the Subcommittee on Water and Power Resources, on S. 716 and S. 991, 92nd Congress, 1st Session. U.S. Government Printing Office, Washington, D.C. p. 141.

The Commission appreciates the fact that prototype experience with a single process using water from one source may not be transferable fully to plants using other feed water sources or desalting processes and that other prototype plants may be desirable. This is a matter which will need to be considered in the light of experience with the initial prototype plant and of the results of the continuing research and development program.

CONCLUSIONS ON DESALTING

Because of increasing future water demands and relatively fixed natural supplies of water, it is likely that desalting will play a significant future role in the United States. This applies especially to the use of smaller desalting plants, less than 10 million gallons per day (m.g.d.) capacity, in areas where other supplies are costly, where there are natural supplies of brackish water, where existing supplies need to be upgraded, or where point-sources of dissolved solids can be treated. There probably will be significant opportunities also for plants of up to 50 m.g.d. or larger as an incremental supply or for intermittent and conjunctive operation with existing surface and ground water sources. Large plants in the 50 to 250 m.g.d. range offer promise for desalting sea water primarily at this time through dual-purpose technology (e.g., desalting and power production), but the extent of this potential cannot be established without prototype experience. Still larger dual-purpose power generation and desalting plants up to 1,000 m.g.d. in size have been considered and analyzed for irrigation and industrial purposes, but they involve still greater uncertainties. Desalting projects using energy from outside sources are becoming less and less attractive as the cost of energy increases. They are only really attractive when they utilize or make possible the more efficient use of waste heat that might otherwise be lost, or a source of natural heat such as geothermal or solar energy.

There are certain policy matters relating to the future course of the Federal effort in any national desalting program. The first is whether the basic desalting processes are sufficiently developed so that private industry can assume most of the future research and development costs for small-sized plants. Many of the processes are now in commercial operation and the Commission believes that desalting research and development is far enough advanced to leave the most important design, construction, and operational risks for desalting plants smaller than 10 m.g.d. using the distillation process but that important improvements in the reverse osmosis and freezing processes may occur and research in these areas should continue.

The Commission believes that federally sponsored research and development on small desalting plants (less than 10 m.g.d.), except for the reverse osmosis and freezing processes and for other processes needed in connection with large plant development, should be gradually eliminated over a 3-year period. The Federal research and development effort should be continued with respect to development of larger desalting plants and multipurpose desalting plants.

The second policy matter concerns the magnitude of the Federal Government's desalting research program as that program relates to other Federal research programs. In recent years, the U.S. Office of Saline Water (OSW) program has been on the order of $27 million annually. About half of this was for demonstration purposes. The OSW program has been about double that of the Office of Water Resources Research (OWRR) (also in the U.S. Department of the Interior) and about four times the Bureau of Reclamation's program of research in precipitation modification. The level of funding for research and demonstration by OSW appears appropriate. Any disparity between OSW and OWRR with respect to available funds would seem to reflect a deficiency for OWRR rather than an excess of funding for desalting.

Third, there should be some reshaping of the desalting program. There is need for more study relating to the application of desalting to other supply sources—desalting for interim use or in staged developments and for conjunctive uses. There also is need to give detailed study to the use of interruptible energy for desalting purposes. Applications of desalting to environment improvement will play an increasingly important role as wastewater criteria become more severe. Research and development to improve the capability to meet these requirements should continue.

A fourth matter is that of the proposed prototype program. While the Commission endorses the concept of Federal assistance for a large prototype desalting plant for research and development, it has some apprehension that the precedent might be used to justify Federal funds for other large plants to follow. While it is possible that future developments in carefully selected instances where private capital will not be made available might justify some Federal support, the Commission's endorsement at this time is limited to one large prototype plant.

FROM: Preliminary Long Range Water Supply Study
NEWS, Dept of the Army, North Atlantic Div.
NOV 1971

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E-6. ENVIRONMENTAL CONSIDERATIONS

In considering placement for any type of desalting plant, environmental considerations are as important as any other factor. Remember - pure water is not the only product. A plant will produce extremely concentrated brine as an effluent, plus any waste products from the power source, such as soot, heat, smoke, toxic gasses, etc. So far as the brine effluent is concerned, plant placement is somewhat contraindicated where the outfall cannot mix with waters such as those to be found on the open coastline. Special design procedures would be required in the cases of estuaries or areas with restricted water interchange, as any life forms present would be adversely affected. Inland plant location causes even more problems, as brine disposal may violate pollution laws. Two methods of disposal have been studied: (1) evaporation to dryness, and (2) deep-well injection.

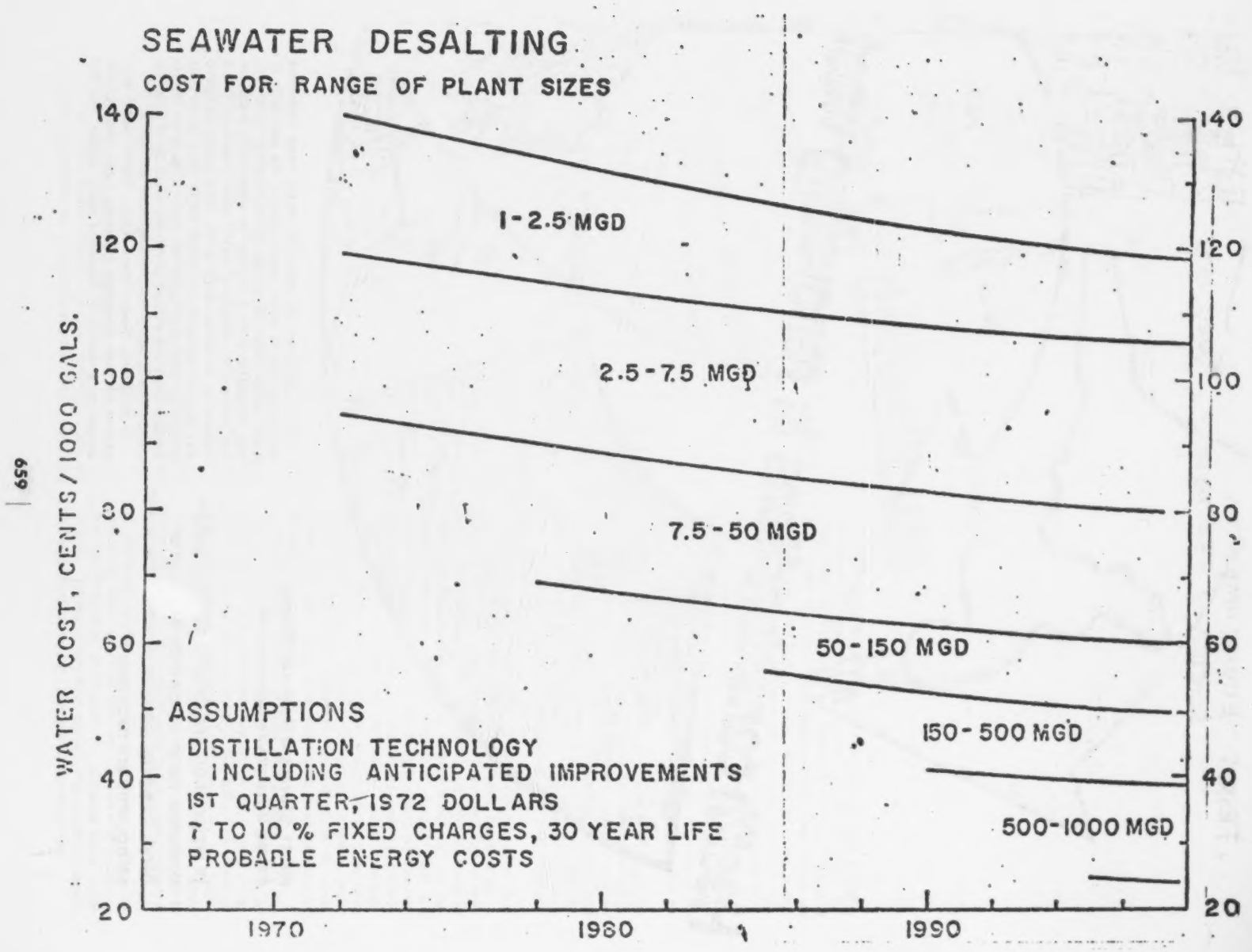
Evaporation is expensive, though this is highly dependent on land costs, while injection-method costs are estimated at 25 to 70 cents per 1,000 gallons of brine. Other methods are currently under investigation.

E-7. AESTHETIC CONSIDERATIONS

Visual impact is another important parameter, as is consideration of land use. Factors amenable to the situation of a desalting plant, such as protection by sandy beaches, gently sloping terrain, proximity to population zones, etc., are the same sought by commercial development, and since a desalting plant is a heavy industrial-type structure, aesthetics may be cited as a valid argument in cases of less-than-ideal proposed placement.

E-8. PRESENT DAY EVALUATION

Existing desalting operations are characterized by several constraining features, among the most important being: high operating costs; limited plant size; and the problem of brine disposal. In the future, as breakthroughs in technology are realized, several of the constraints are expected to be reduced, and desalting may prove to be an efficient means of water supply for coastal and estuarine areas of the northeast. At present, however, the best application may be installation of plants for use only during peak demand periods, coinciding with drought conditions. The facilities, of course, must be coupled with a suitable source of power.


SEAWATER DESALTING
COST FOR RANGE OF PLANT SIZES
WATER COST, CENTS / 1000 GALS.
140
120
100
80
60
40
20
1-2.5 MGD
2.5-7.5 MGD
7.5-50 MGD
50-150 MGD
150-500 MGD
500-1000 MGD
ASSUMPTIONS
DISTILLATION TECHNOLOGY
INCLUDING ANTICIPATED IMPROVEMENTS
1ST QUARTER, 1972 DOLLARS
7 TO 10 % FIXED CHARGES, 30 YEAR LIFE
PROBABLE ENERGY COSTS
1970
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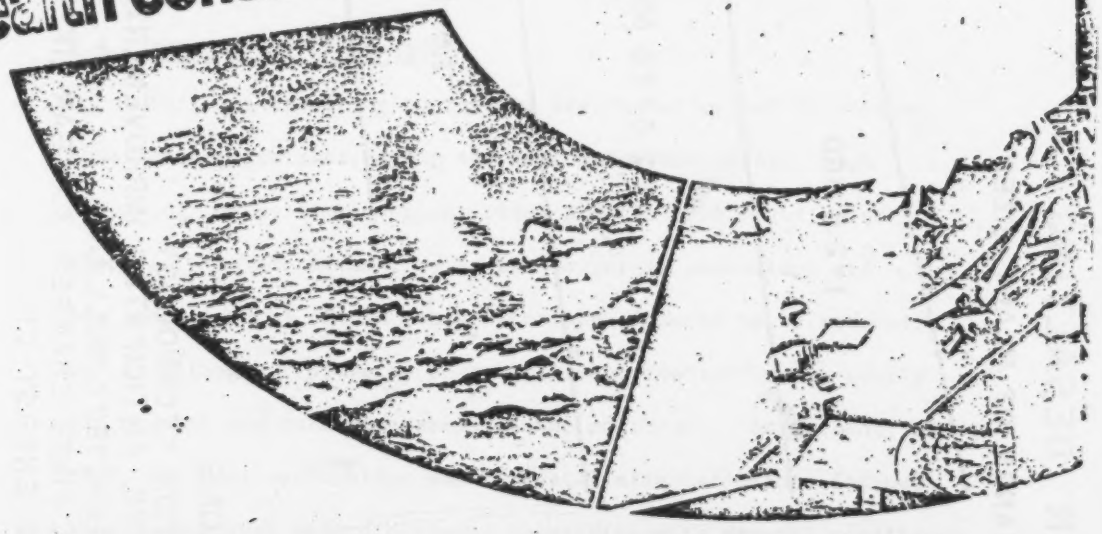
1990
659

FROM: ENVIRONMENTAL SCIENCE & TECHNOLOGY JULY 1973

127

Health considerations in renovating wast



Hillel I. Shuval and Nachman Gruener
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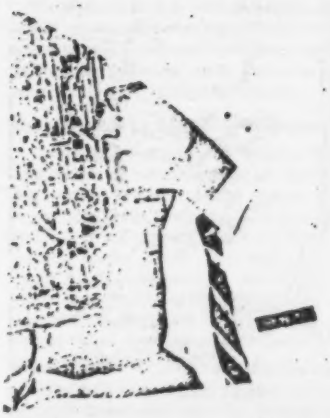
In water-short and heavily polluted areas, complete water reuse may be close at hand; however, countless precautions and safeguards are necessary

The development of advanced waste water treatment technology has in recent years brought the possibility of waste water reuse for domestic consumption under active consideration in a number of water-short areas. In the process of developing waste water treatment trains capable of removing much of the incremental inorganic and organic contaminants which might have deleterious effects on water courses, it has become apparent that in certain cases the effluent produced could be of a quality comparable to recognized drinking water standards.

In Windhoek, South West Africa, waste water processed by such advanced treatment trains has actually served as a source of municipal water supply, and the



ater for domestic use

adequacy of treatment has been justified by comparing the effluent quality with drinking water standards. A number of other cities, including Denver, Colo., and Tel-Aviv, Israel, are in the preparatory stages for such planned reuse for domestic purposes.

At this point it is appropriate to ask whether man's knowledge of the toxicological and epidemiological implications of waste water renovation for domestic consumption is sufficient.

Adequacy of drinking water standards

The U.S. Public Health Service (USPHS) Drinking Water Standards list 20 chemical parameters, only nine of which serve as absolute grounds for rejecting a supply as unsafe for human consumption. The World Health Organization (WHO) Drinking Water Standards contain a few more chemical parameters which may serve as grounds for rejecting a supply. Neither of these widely known and accepted standards lists more than a few synthetic organic compounds despite the fact that hundreds of such chemicals may find their way into municipal and industrial waste water, and many of them are known for their potential deleterious effects on human health. For that matter, neither do these standards exhaust the list of potential inorganic toxicants that may be found in industrial wastes.

Conventional drinking water standards were originally based on the assumption that water for human consumption would generally be drawn from groundwater sources or protected uncontaminated surface water sources, and that the limited number of chemical parameters included were adequate for most situations, then considered feasible. This assumption is rarely true for most surface supplies of today.

The unbridled increase in the use of hundreds of new and often structurally complex synthetic compounds in industry and agriculture has led to intensive study of their toxic effects. In addition to acute toxic effects, some of these chemicals have chronic effects which can be detected only after long-term exposure. Among them are chemicals whose effects have been found to be carcinogenic, mutagenic, and teratogenic as well as causing other deleterious health effects. Several hundred threshold limit values for such industrial substances in air have been established in the field of industrial hygiene, while some 100 maximum allowable concentrations for pesticides and other toxic chemicals have been established under food regulations.

The drinking water standards of the USSR were the first to recognize the scope of the problem and now include some 300 chemical parameters with more under study. Certainly not everyone of the 300 or so chemical standards for drinking water established by the USSR health authorities is of toxicological importance, since many were established on organoleptic grounds alone. Nevertheless, the differences among the large number of standards on the USSR list and the very limited number of standards presently considered adequate in the USA and many other countries indicate the extent of problems that will have to be faced when the undiluted waste water of a city, including industrial wastes, has to be processed to the point of becoming fit for human consumption.

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The mere comparison of the quality of the final effluent against those standards currently listed in USPHS or WHO drinking water standards leaves too many questions unanswered to be accepted as adequate evidence that such an effluent is completely safe from the public health point of view. While some of the complex, nonbiodegradable synthetic compounds under discussion may be harmful to health at concentrations at the parts-per-billion level, advanced waste water renovation technology still cannot reduce COD or TOC to an absolute zero concentration, and except under unusual circumstances must be satisfied with residual concentrations of such organics at about the 10-ppm level. Not enough is known about the true identification of the residual microchemical pollutants, both inorganic and organic, which vary widely from one situation to the next depending on the nature of the industrial wastes which enter the sewerage system.

Microchemical pollutants in waste water

Numerous efforts have been made to gain a better understanding of toxic hazards of modern synthetic chemicals that find their way into waste water and ultimately into drinking water sources. However, there are many difficult problems in concentrating, extracting, and identifying such compounds, many of which still may be unknown breakdown products of more complex chemicals that have undergone partial biodegradation. In 1960, researchers at the Taft Sanitary Engineering Center were able to identify fewer than 40% of the soluble organics remaining in biologically treated sewage, and these were described only in general terms such as either extractable matter, protein, tannin, lignin, or alkyl benzene sulfonate.

DDT, aldrin, orthochlorinitrobenzene, tetralin, naphthalene chloroethyl ether, acetophenone, diphenyl ether, pyridine, phenols, nitriles, acidic materials, and miscellaneous hydrocarbons including substituted benzene compounds, kerosine, synthetic detergents, aldehydes, ketones, and alcohols have also been identified in polluted river water. Some of these substances are known to be toxic. Many other compounds, undoubtedly present, remain unidentified. The application of chromatographic and spectrophotometric methods as well as mass spectrometry has now made analysis easier.

The conventional methods of waste water treatment leave many potentially hazardous dissolved chemicals unchanged. The concentration of contaminants has been shown to increase in downstream communities as water is used and reused and as the percentage of unremoved residual refractory chemicals grows.

Carcinogens in waste water

Petroleum products and refinery wastes are among the possible mutagenic and carcinogenic substances that may appear in municipal waste water. Various polynuclear aromatic hydrocarbons have been recovered from sewage sludge, among them the known carcinogens, 3,4-benzpyrene and 1,2-benzathracene. Carcinogenic aromatic amino compounds, such as betanaphthylamine and benzidine, originate in dye and rubber works and may be released to sewer systems together with nitroanalogs used in the production of amino compounds, such as aminoazodyes, amino stilbenes, and tri- and diphenylmethane dyes. Pharmaceutical factories, textile dyeing plants, plastic production, and similar industries are

Drinking water. *Industrial wastes discharged into streams could eventually be withdrawn for municipal water supplies*

sources of these organics. Some of the intermediates, such as orthochloronitrobenzene, have been found in the Mississippi River in appreciable quantities and appear to be quite stable. Chloronitrobenzene, for example, discharged to the Mississippi at St. Louis, Mo., was still demonstrable in the drinking water drawn at New Orleans, La., hundreds of miles and many days' flow downstream.

New Orleans has been shown to have a cancer of the bladder rate three times higher than two other southern cities supplied with less polluted water. It has been hypothesized that there may be some association between cancer of the bladder in New Orleans and the contaminants in the water. This possibility must, however, raise the question as to whether potentially hazardous organics are removed adequately by activated carbon treatment which is probably the most effective treatment process available at this time. Polynuclear aromatic hydrocarbons, potentially dangerous carcinogens found in waste water, are poorly removed by activated carbon filtration if flow rates are low enough.

Microbiological problems

While most bacterial pathogens can be effectively inactivated by chlorination and other conventional disinfection procedures, there is ample evidence that some of the enteroviruses are manyfold times more resistant than bacteria to the same disinfection processes. Infectious hepatitis has been transmitted by sewage-contaminated water on many occasions, and in some cases the virus appears to have passed through conventional water treatment plants which have included disinfection by chlorine.

Enteric virus levels in raw sewage have been shown to be about 1–10 per ml while their concentration in heavily contaminated river water, which may lead to epidemics of infectious hepatitis may be 1 per 10 liters or even less. Laboratory techniques for detecting such low levels of viruses in water are still in the developmental stage and present one of the major obstacles in studying the efficiency of waste water renovation processes as to virus removal. Another problem arises from the fact that it may take five days or more before the results of a virus assay of water can be completed. Effective methods of assuring virus inactivation in waste water treatment still leave something to be desired although there is growing evidence that adequate concentrations of free available chlorine (HOCl) with sufficient contact time can be highly effective in reducing enteric virus levels. Ozone is particularly promising as a virucidal agent for water and waste water treatment.

Nevertheless the effectiveness of any proposed waste water renovation treatment train must be fully evaluated as to its virus removal efficiency and ways must be found to monitor routinely such plants to assure their continued effectiveness in removing viruses.

Toxicological evaluation of renovated waste water

There are two possible approaches to the toxicological evaluation of renovated waste water to be used as drinking water. The first would require establishment of maximum allowable concentrations or limits for each of the potentially hazardous chemicals that may be found in renovated waste water. The approach that has been developed by toxicologists in setting tolerance limits for food additives and chemical contaminants in food has been to establish acceptable daily intake (ADI) levels for man. These ADI are based on all relevant toxicological data available at the time of evaluation including data from cases of human exposure which are usually limited. After the "no effect" level is determined and a certain safety factor is introduced, the ADI can be established. Such figures can then provide the toxicological basis for establishing tolerance levels or maximum allowable concentrations in food, water, and air based on known consumption patterns and realistic levels of contamination which is unavoidable. To establish such figures for water, due consideration must be given to the total body burden from all environmental sources.

The toxicological evaluation of chemicals in the environment cannot be simplified to take into account acute or subacute effects alone. Today such evaluation must include effects from long-term exposure and studies for carcinogenicity, mutagenicity, teratogenicity, and various biochemical and physiological effects. Even if the specific toxicity of defined industrial and agricultural chemicals is established, the possible toxic effects of their breakdown products may be more difficult to determine. Natural biodegradation or specific waste treatment processes may lead to the development of new compounds having toxic properties quite different from those of the parent compound. Work to identify these breakdown products and to study their toxic effects is required.

Another factor complicating the toxicological evaluation of heavily polluted water or renovated waste water is the combined and possible synergistic effect resulting from the exposure to a mixture of toxic and nontoxic chemicals. Increased toxic impact of such combinations is known to occur under certain circumstances, and the case of renovated waste water must take into account such possibilities. Although much is to be gained by establishing proper tolerance levels for many of the known toxicants that might appear in renovated water, this approach will take a long time to develop and even then will not cover all possible toxic effects.

For these reasons a second approach is required. A full toxicological evaluation should be carried out on the water intended for human consumption with its real mixture of known and unknown residual chemicals remaining after treatment.

Long-term feeding experiments with more than one species of experimental animal should be required as well as other toxicological tests. Such studies should preferably include feeding concentrates of the residual chemicals in the final processed water as well as the normal unconcentrated effluent. Concentration techniques used must avoid being selective as is the case with activated carbon and must not lead to the breakdown of the chemicals involved by overly harsh treatment such as high-temperature distillation. Low-temperature vacuum distillation, reverse osmosis, or lyophilization might be possible approaches.

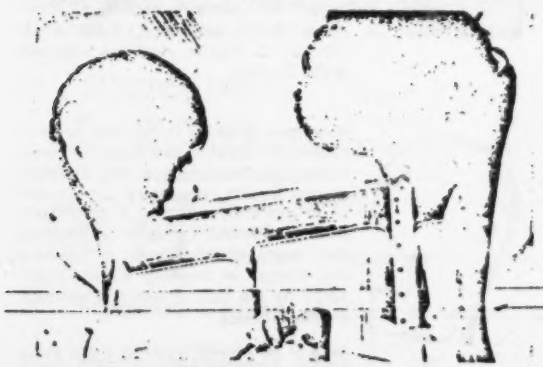
Most governments require the full toxicological evaluation of any new drug or food additive before allowing its commercial use. The requirements for evaluating renovated waste water with its many and often complex unknowns should be at least as rigorous.

Epidemiological evaluation

No matter how thoroughly a toxicological evaluation is made, the problem of extrapolating the findings with laboratory animals to fit the human situation always remains. With drugs of potentially great medical importance, human trials are held after completion of the toxicological evaluation. In the case of new food additives which are usually less essential to human welfare than drugs, negative findings in the toxicological evaluation do not automatically mean that the new chemical will be allowed for use in human food. It must be demonstrated that the chemical will make a significant contribution to improving the quality or preservation of the foods in which it will be used and that there is no reasonable nonchemical alternative. In water-short areas, total water renovation can often be justified as being of potentially great importance to human welfare as well, particularly when no alternative water sources are available. As with other intentional exposure to chemicals in the environment, the benefits must be considered in light of any possible risks involved, if human exposure is to be allowed.

A considerable body of information has been built up concerning the effect on human health of many of the environmental contaminants discussed in this paper as a result of direct exposure of humans under various industrial situations. Further information has been gained by the accidental exposure of humans to certain toxic materials.

If waste water renovation for domestic consumption is to become widely accepted, there will be a need at some stage to carry out a full-scale epidemiological evaluation of the impact of such reuse on the health of the population exposed. It may be difficult to choose an appropriate population group for such a study, but to the extent that certain communities in water-short areas have already gone ahead with waste water reuse for drinking water, every effort should be made to carry out a thorough



Testing. *Before renovated waste water is used as a water supply source, health effects must be thoroughly evaluated*

baseline health evaluation of a sample population before the introduction of renovated water and then a follow-up of the same group as a panel study, over a five- or 10-year period. Such opportunities will be few and far between, and every effort should be made to gain as much data from each case as is possible. The study should include details on potential water-borne infectious diseases, particularly of virus etiology as well as long-term health effects of chemicals.

A promising alternative to such a study with a population exposed to planned waste water reuse would be a series of studies of populations exposed to indirect or unintentional waste water reuse. Such population groups are easier to identify than might be imagined since many millions of people throughout the world are, in fact, consuming some form of renovated waste water every day and have been doing so for years. Some 15% of the flow of the Ohio River is fully or partially treated municipal or industrial waste water. Millions of people in the Rhine River Basin consume water from the river which at times of low flow may contain as much as 40% of industrial and municipal waste water.

Unintentional, and in many respects, uncontrolled reuse of waste water is now very widely practiced and provides a basis for evaluating the health impact of such use as well as the expected impact of fully engineered and carefully controlled direct waste water reuse of the type under discussion in this paper.

Monitoring waste water reuse programs

The nature of a monitoring or quality control program for products produced for human consumption should vary according to the degree of risk to health involved. Conventional water supply monitoring programs have in the past assumed that the product is basically a safe one and that it can be supplied to the consumer directly after processing without waiting for the results of quality control tests. Bacteriological test results are usually available 24–48 hr after sampling, while routine tests for toxic chemicals, when they are made, may be available only after many days. The water tested has usually been consumed by the population by that time.

In the case of a plant for renovating waste water for human consumption, it would appear necessary to require a more rigorous monitoring and quality control regime than that currently practiced by the water supply industry. Technical breakdowns and human failures at such a plant might lead to major health hazards. It would not be illogical to require that renovated water be fully tested and certified as safe before its release to the general water supply system. With improved bacteriological techniques, results can be obtained within 24 hr, as can the results of most of the important chemical tests, many of which can be automated. Ways of carrying out rapid toxicological evaluation of the finished water with bioassay techniques should be developed. For the moment, virus assays require at least three days for completion, but here too, more rapid assay techniques are under study and may become available.

Renovated water could be produced and held in batches until completion of the quality control tests, before being released. This will add additional costs to waste water renovation plants, but the additional safety obtained would justify the expenditure. Certainly such precautions should be practiced in all early plants until it can be demonstrated that less stringent quality control measures are adequate.

The approach presented in this article may appear to be overly cautious and place too heavy a burden on future waste water renovation programs. In answer, we must say that our criticism of current drinking water serves as a source of drinking water no less than to the special case of waste water renovation. In fact, indirect, unplanned waste water reuse of the former class may well be a greater risk than planned reuse which would include treatment processes better capable of coping with the organic pollutants found in waste water. Unplanned waste water reuse is far too widely practiced today, with too few controls, to allow one to feel complacent.

However, planned waste water reuse carries a heavy responsibility with it, since it involves the full engineering and health responsibility from the beginning to the end without the intervening hand of "nature." In such a project, the designers, operators, and health authorities who must give their approval, must carry the full responsibility of any adverse health effects which may result even if it can be shown that communities consuming polluted surface water are exposed to equal or greater risks.

We tend to agree that such communities are indeed exposed to undesirable health risks and would propose an equal tightening up of standards, treatment procedures, and quality control for all cases of waste water reuse whether direct or indirect.

Additional reading

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J. Borneff, R. Fisher, Part IX, "Investigations of filter-activated carbon after utilization in water plant," *Arch. Hyg. Bakteriol.*, 143, 1–16 (Ger.) 1962.

World Health Organization, "Reuse of Effluents: Methods of Wastewater Treatment and Health Safeguards," Tech. Report. Series No. 517, 63 pp, Geneva, 1973.

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Some of the material presented in this article is based on unpublished reports of the World Health Organization, their expert consultants and advisory groups.

FINAL ENVIRONMENTAL IMPACT STATEMENT

SUMMARY SHEET

NORTHFIELD MOUNTAIN DIVERSION
MILLERS RIVER DIVERSION
NORTHEAST WATER SUPPLY STUDY

( ) Revised Draft (X) Final Environmental Statement

Responsible Office: U. S. Army Engineer Division, New England, Waltham, Massachusetts

1. Name of Action: ( ) Administrative (X) Legislative (Federal)

2. Description of Action: Involves solutions for meeting future water supply requirements for Eastern Massachusetts and explores various alternative ways to meet the projected needs for this region. Proposals include diversion during high flow periods from the Connecticut River via the Northfield Mountain pumped-storage facility directly to Quabbin Reservoir and by three other alternative methods to utilize and transport water from the Millers River Basin to the Quabbin Reservoir.

3. a. Environmental Impacts: Implementation would assure availability of projected water requirements for Eastern Massachusetts. Provides means to keep water quality high in Quabbin Reservoir by slowing down present depletion rate. An increased nutrient level in Quabbin Reservoir is expected. Depending on the alternate chosen, certain lands and waters will be dedicated to water supply in the Millers River Basin. Millers River water quality will be improved under two alternatives. May create a shift in present fishing patterns in Quabbin Reservoir. High diversion rates would cause appreciable loss of flow in the mainstem Millers River during portions of the diversion period.

b. Adverse Environmental Impacts: May include a temperature rise below the diversion point on the Millers River as well as a probable lessening of the sediment load and a partial loss of flushing action in the stream. No adverse effects are predicted for the mainstem of the Connecticut River or its estuary. No significant changes are predicted for Quabbin Reservoir. Some biota will become entrapped or entrained by the Northfield pumped-storage project.

4. Alternatives:

a. No Action
b. Weather Modification
c. Desalinization
d. Importation
e. Wastewater Reuse
f. Ground Water Resources
g. Dual Water Supply Systems
h. Other Diversion Sites
i. Water Demand Control
j. Re-examination of Release Schedules
k. Local Resource Potential
l. Population Zoning and Regulations

5. Comments requested (See attached sheets)

6. Draft statement sent to CEQ 11/14/72.
Final statement sent to CEQ _____.

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Federal

First Coast Guard District
Federal Aviation Administration
Department of the Interior
Soil Conservation Service
Environmental Protection Agency
Federal Highway Administration
Bureau of Sport Fisheries & Wildlife
Department of Commerce
National Marine Fisheries Service
Office of Economic Opportunity
Federal Power Commission
New England River Basins Commission
U.S. Geological Survey
Department of Health, Education and Welfare
Department of Housing and Urban Development
National Park Service
Bureau of Outdoor Recreation
U.S. Department of Transportation
North Atlantic Division, Corps of Engineers

State

Conn. Water Resources Comm.
Conn. Office of State Planning
Conn. Board of Fisheries and Game
Conn. Department of Environmental Protection
Conn. Department of Community Affairs
Conn. Department of Public Health
Conn. Shell Fish Commission
Conn. Department of Agriculture
Conn. Institute for Water Resources
Hartford Metropolitan District Comm.
Mass. Office of Planning and Programming Coordination
Mass. Department of Public Works
Mass. Department of Natural Resources
Mass. Department of Water Resources
Mass. Division of Fisheries & Game
Mass. Department of Public Health
Mass. Agricultural Experiment Station
Mass. State Geologist
Mass. Water Resources Research Center
Mass. State Research Director
Mass. Department of Commerce and Development
Mass. Department of Community Affairs
Boston Metropolitan District Comm.

State (Cont'd)

N.H. Water Supply and Pollution Control Comm.
N.H. Water Resources Board
N.H. Fish & Game Department
N.H. Water Resources Research Center
N.H. Office of State Planning
Office of the Governor of N.H.
N.H. Natural Resource Council
N.H. Department of Public Health
R.I. Water Resource Center
R.I. Department of Natural Resources
R.I. Department of Health
R.I. Statewide Planning Program
R.I. Water Resources Board
Vt. Resource Research Center
Vt. Department of Water Resources
Vt. Planning and Community Services Agency
Tri-State Transportation Comm.
Southern N.H. Planning Comm.
R.I. State Comp. Trans. & Land Use Planning Program
Connecticut Regional Planning Agencies
- Capital
- Central
- Southeastern
- Conn. River Estuary
- Litchfield Hills
- Midstate
- Northeastern
- Windham
- Greater Bridgeport
- Central Naugatuck Valley
- Southwestern
- Valley
- South Central
- Conn. Interregional Planning Program

Massachusetts Regional Planning Agencies
- Metropolitan Area
- Old Colony
- Southeastern
- Montachusetts
- Central Merrimack Valley
- Northern Middlesex Area
- Berkshire
- Lower Pioneer Valley
- Central Massachusetts
- Cape Cod
- Dukes County
- Franklin County

Private Organizations

Portland Water District
Connecticut Water Company
Massachusetts Audubon Society
Anderson-Nichols, Inc.
Union of Concerned Scientists, MIT
New England Natural Resources Center
League of Woman Voters, Mass.
League of Woman Voters, Conn.
Charles River Valley Group of the L.W.V.
Curran Associates, Inc.
Normandeau Associates, Inc.
The Maine Assoc. of Conservation Comm.
WCAT-Berkshire Broadcasting
Orange Enterprise & Journal
Orange Board of Health
Abt Associates, Inc.
Essex Marine Laboratory, Inc.
Associated Industries of Mass.
New England Water Works Assoc.
American Water Works Assoc., Inc.
Salem and Beverly Water Supply Board
Westfield River Watershed Assoc.
Trout Unlimited
Millers River Watershed Council
Fenton G. Keyes Assoc.
Broadmoor Sanctuary
Nashua River Program
Massachusetts Wildlife Federation
Worcester Telegram and Gazette
The Outdoor Message
National Wildlife Federation
Appalachian Mountain Club
Water Department, Cambridge
Ipswich River Watershed District Comm.
Conn. River Valley Flood Control Comm.
Merrimack River Valley Flood Control Comm.
Thames River Valley Flood Control Comm.
Conn. River Watershed Council, Inc.
Parker River Watershed Council
Farmington River Watershed Assoc.
Housatonic River Watershed Assoc.
Canoe River Watershed
Mystic River Watershed Assoc.
North and South Rivers Watershed Assoc.
Ad Hoc Committee
Blackstone Valley Watershed Assoc.
Charles River Watershed Assoc.
League of Woman Voters of R.I.
League of Woman Voters of N.H.
League of Woman Voters of Vt.

Private Organizations (Cont'd)

Conn. Assoc. of Conservation Comm., Inc.
Conn. Audubon Council
Conn. Forest and Park Assoc., Inc.
The Nature Conservancy, N.H.
Council of Sportsmen's Clubs of Mass., Inc.
Mass. Assoc. of Conservation Districts
Mass. Forest and Park Assoc.
The Trustees of Reservations
Federated Sportsmen's Clubs of N.H., Inc.
Audubon Society of N.H.
Land Use Foundation of N.H.
N.H. Assoc. of Soil Conservation Districts
N.H. Natural Resources Council, Inc.
Seacoast Anti-Pollution League, N.H.
Society for the Protection of N.H. Forests
Statewide Program of Action to Conserve Our Environment, N.H.
Audubon Society of R.I.
Environmental Council of R.I., Inc.
R.I. Assoc. of Soil and Water Conservation District Supervisors
Vermont Natural Resouces Council
Merck Forest Foundation, Inc.
The Nature Conservancy, Vt.
Vermont Assoc. of Conservation Districts
Environmental Protection Comm., Conn.
N.E. Research, Inc.
Mass. Water Works Assoc.
New England Natural Resources Center
Worcester County League of Sportsmen
Merrimack Valley Region Assoc.
Agency of Environmental Conservation, Vt.
Conn. River Estuary R.P.A.
Ipswich River Water District
Neponset Conservation Assoc.
Westport River Improvement Assoc.
Essex County Greenbelt Assoc.
Ternmile River Task Force
Lake Cochituate Watershed Assoc.
Reading Greenbelt Assoc.
Orange Conservation Comm.
Civil Engineering Dept. , Univ. of Conn.
Marine Resources Committee
Coastal Research Center , Univ. of Mass.
National Foundation For Environmental Control
Sierra Club
Environment Inform. Ctr, Inc.
New York Times
Greater Boston Ecology Action Ctr.
Metropolitan Area Plng. Council
Nashua River Watershed Assoc.
Mass. Port Authority

Private Organizations (Cont'd)

Conn. Wildlife Federation, Inc.
Save The Wetlands Committee, Ct.
Conn. Action Now, Inc.
Conn. Audubon Society
Conn. Assoc. of Soil and Water Conservation Districts, Inc.
N.H. Water Works Assoc.
Environmental Conservation
Middlesex Conservation District

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Mr. David Stickel
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A. Comments Received:

Federal:

U.S. Department of Agriculture, Soil Conservation Service
Department of Housing and Urban Development
U.S. Department of Transportation, Federal Highway Administration
Federal Power Commission
Office of Economic Opportunity
U.S. Environmental Protection Agency
U.S. Department of Commerce
U.S. Department of the Interior:
Bureau of Mines
Bureau of Outdoor Recreation
Bureau of Sport Fisheries and Wildlife
National Park Service

State of Connecticut:

Department of Environmental Protection

Commonwealth of Massachusetts:

Metropolitan District Commission
Department of Commerce and Development
Division of Fisheries and Game
University of Massachusetts, Agricultural Experiment Station
Water Resources Commission

State of New Hampshire:

Office of the Governor (State Clearinghouse)
Water Supply and Pollution Control Commission

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State of Rhode Island and Providence Plantations:

Statewide Planning Program

Local:

Franklin County, Massachusetts, Department of Planning
City of Hartford, Connecticut
Town of Montague, Massachusetts
Natick Conservation Commission, Massachusetts

Private Organizations:

Connecticut Audubon Council, Inc.
Connecticut Forest and Park Association, Inc.
Connecticut River Watershed Council, Inc.
Lower Pioneer Valley Regional Planning Commission
Massachusetts Audubon Society
Connecticut River Ecology Action Corporation
Millers River Watershed Council, Inc.
League of Women Voters, Holyoke Area, Massachusetts
Lake Cochituate Watershed Association, Inc.
Save Our Streams
League of Women Voters, Massachusetts
Sierra Club, New England Chapter

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INTRODUCTION

The 89th Congress recognized that the assurance of adequate supplies of water for the great metropolitan centers had become a problem of such magnitude that the welfare and prosperity of the United States required the Federal Government to assist in its resolution. Consequently, the Congress enacted the Northeastern United States Water Supply (NEWS) Study on 27 October 1965, under Title I of Public Law 89-298.

A copy of the law, with a map of the study area on its reverse side, is attached. It authorized the Secretary of the Army, acting through the Chief of Engineers, to prepare plans to meet the long range water supply needs of the Northeast, in cooperation with Federal, State and local agencies. The Chief of Engineers, in turn, assigned responsibility for the NEWS Study to the Division Engineer, North Atlantic.

The NEWS Study area includes those river basins within the United States which drain into Chesapeake Bay, into the Atlantic Ocean north of Chesapeake Bay, into the St. Lawrence River, and into Lake Ontario. The study area, therefore, includes all of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, and the District of Columbia, and parts of New York, Pennsylvania, Maryland, Virginia, and West Virginia.

An area of approximately 200,000 square miles, the area contains a population of about 50 million persons, which is projected to reach about 85 million by the year 2020. Some 60 percent of the present population is concentrated in the five metropolitan areas of Boston, New York, Philadelphia, Baltimore and Washington. It includes twenty of the nation's one hundred largest cities. The municipal water suppliers of the region serve populations varying from less than 100 to 8.5 million. Although the area has an average annual precipitation rate of about 40 inches, as compared to the national average of 30 inches, precipitation deficiencies in some parts of the area were up to 50 inches during the October '61 to December '65 period. The area's vulnerability to water shortage is revealed by the fact that some 14 million people, about 28 percent of the population, were restricted to some degree in their use of water during this drought. Although public awareness of the problems of water supply is increased by drought experiences, drought is not the only reason for concern. Available supplies of water of good quality will soon be inadequate, even under normal conditions, to meet the needs of the expanding population and industrial growth.

The objective of the NEWS Study is the preparation of a coordinated general plan for essential water supply development in the Northeast which will recommend to the Congress an active program for Federal, State, local, and private organizations. Such plans shall provide for appropriate financial participation by the States, political subdivisions thereof, and other local interests. It will thus provide a public forum where all vitally concerned with the water supply problems of the area can be heard in developing a plan to resolve one of the domestic problems now facing the United States.

In achieving its objective, the NEWS Study is presenting a regional assessment of present and future water supply needs and will explore alternatives for their solution. The study effort is being fully coordinated through the various Federal, State, local and private agencies and organizations. This coordination will assure that plans are consistent with, and integral to, other concurrent water resource planned development being formulated. Thus, the NEWS Study can provide a framework through which all elements may effectively work together toward securing adequate water supplies. During the study, interim reports will be prepared to deal with critical problems which may be encountered. These reports will contain specific recommendations to the Congress for authorization of major reservoirs, conveyance facilities, or treatment facilities, as may be appropriate. The Northfield Mountain Diversion and Diversion from the Millers River[1] Basin are the studies which are the subject of this revised draft Environmental Statement.

The NEWS Study effort was organized and initiated during the last half of 1966 with the preparation of a plan of study and the acquisition of data and reports. There followed a series of initial public hearings; the development of statistical information on public and private water supplies; a summary of drought information, including restrictions and shortages experienced in various communities; an appraisal of the degree of urgency for additional water supply in various regions of the study area; an analysis of the water supply potential of one selected area by the use of advanced statistical hydrologic techniques; and the initiation of studies in specific urgent regional metropolitan areas.

The NEWS Study has established the premise that areas in which the projected demand for water supply in 1980 will probably exceed the present capabilities of the systems will be considered in the "urgent"

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[1] Both projects are included in the New England River Basins Commission 1980 Connecticut River Basin Plan, January 1972.

category. Under NEWS procedures, projects and regional programs for these urgent areas will be developed and made the subject of interim reports which will be submitted to the Congress for authorization. To identify these urgent areas, an initial appraisal was made of the present systems to satisfy the projected 1980 demands. This appraisal included an evaluation of present system capabilities, present and projected domestic and industrial consumption, population expansion and economic growth. The appraisal disclosed four critically urgent areas as follows:

1) Eastern Massachusetts and Rhode Island

2) Western Connecticut - Metropolitan New York City and Northern New Jersey

3) South Central Pennsylvania, Baltimore

4) Metropolitan Washington, D. C.

Once these critical areas had been identified, feasibility detail studies were initiated to investigate alternative engineering solutions. The western Connecticut area, although in the New England Division, because of its geographic proximity to the Metropolitan New York area was studied in conjunction with that region. The second "urgent" need area within New England, i.e. Eastern Massachusetts, was studied by members of the New England Division.

The Division Engineer, New England Division, cooperated in the NEWS Study by preparing an engineering feasibility study for this area. Aimed primarily at the water short areas of eastern Massachusetts, this study included Rhode Island, since evaluation of a potential regional scheme could involve consideration for the future needs of that state. The study, initiated in December 1968, was performed in consultation with representatives of the States of Massachusetts, Connecticut, Rhode Island, and of the New England River Basins Commission. A report of the study results, the engineering alternatives feasible for the area, was prepared and submitted for review and comment in draft form in November 1969. Following a review period and receipt of the review comments, a meeting was held in May 1970 with representatives of the Federal, State, and local agencies and interests to reach agreement on the best future course for the NEWS Study to pursue in continuing studies in the area.

It was agreed that the Corps proceed with detailed studies on the development of Tully Reservoir; initiate detailed studies on the

Northfield Mountain development to complement studies by the Metropolitan District Commission; initiate studies on the requirements for improving the water quality of the Merrimack River together with a detailed investigation of the use of the River as a possible water supply source for the Eastern Massachusetts area; conduct a broad environmental impact study of water supply alternatives; perform detailed studies of the effect of upstream diversion on the estuaries of the Merrimack and Connecticut Rivers; and explore the possibilities of advance site acquisition in Rhode Island.

In addition to the progress meetings, held during the course of the study, four informal information meetings were held within the Millers River Basin. These meetings were held in Athol, Massachusetts on 21 October 1971 and 4 January 1972; in Winchendon, Massachusetts on 2 March 1972, and in Athol, Massachusetts on 8 May 1972.

During December 1971 and January 1972, a series of four formulation stage public meetings were held in Needham, Woburn, Orange and Longmeadow, Massachusetts. These meetings were designed to broaden public participation in the open planning process by describing the on-going studies and receiving audience input. Some people spoke in favor of the plans presented. Others thought that we should concentrate on reducing demand instead of diverting more water to Eastern Massachusetts. A number of people at the Orange meeting suggested that water be diverted from the Millers River itself after pollution abatement. These ideas and others expressed at the public meetings were investigated as part of our studies and considered in the formulation of all plans. Late Stage Public Meetings were held in Waltham and Orange, Massachusetts on July 5 and 6, 1972.

ENVIRONMENTAL IMPACT STATEMENT BACKGROUND INFORMATION

This statement consists of an assessment of the environmental resources affected by the Millers and Connecticut River diversions, an analysis of the probable environmental impacts of each plan, and possible alternatives. The study of the Merrimack River Diversion will be the subject of a separate action.

The following pages describe the efforts of an integrated multi-discipline team of Corps of Engineers personnel, Fish and Wildlife Service Biologists, and services from three environmental and socio-economic impact consulting firms. [1]

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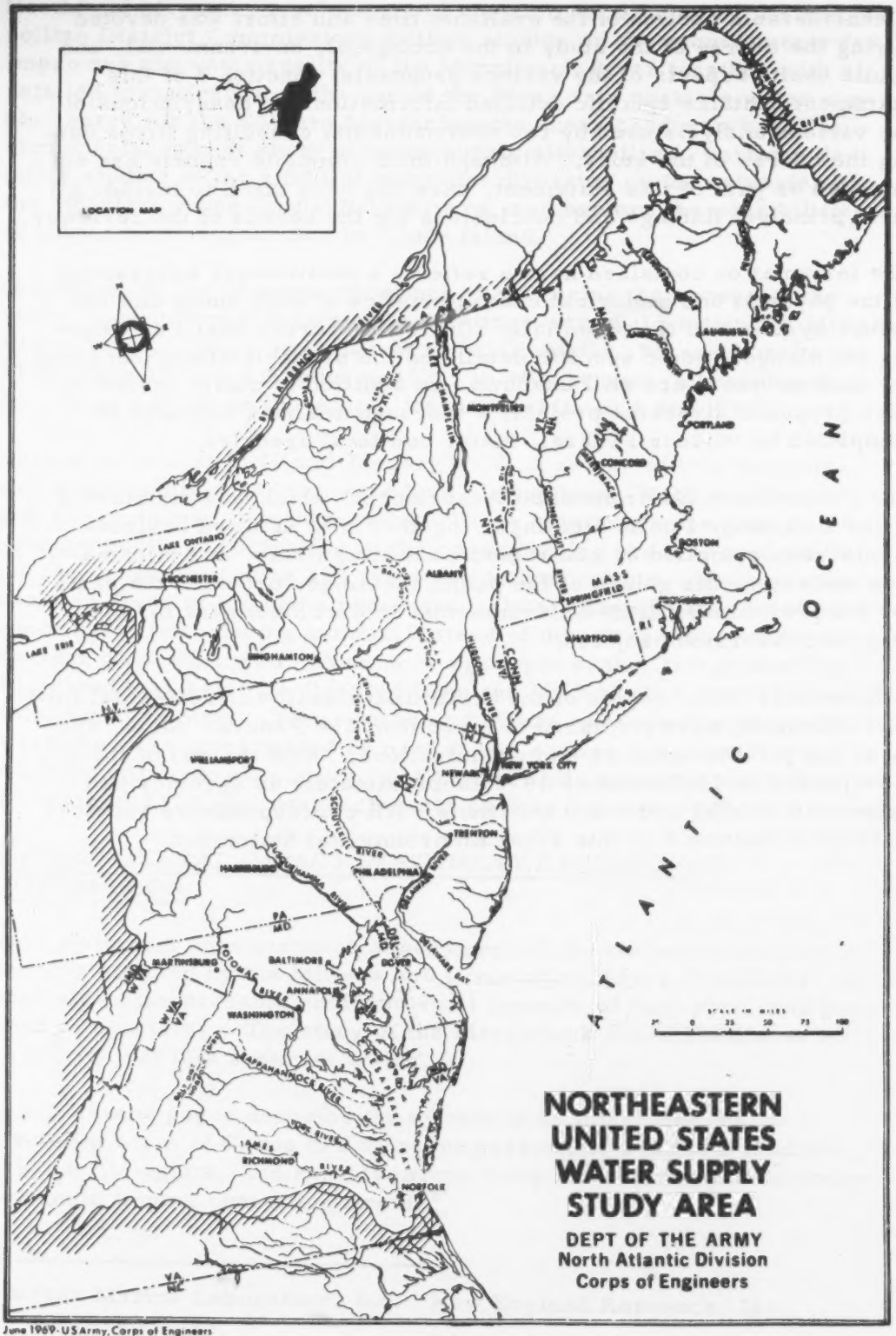
[1] Essex Marine Laboratory, Inc., New England Research, Inc., Abt Associates.

A considerable portion of the available time and effort was devoted during the course of the study to the ecological, environmental, and public health aspects of the various proposals. Section 3 of this statement contains specific detailed information and descriptions of the various analysis used by two environmental consulting firms during the course of the study. Although their complete reports are not included as part of this statement, care has been taken to include all principal findings and conclusions for the benefit of the reviewer.

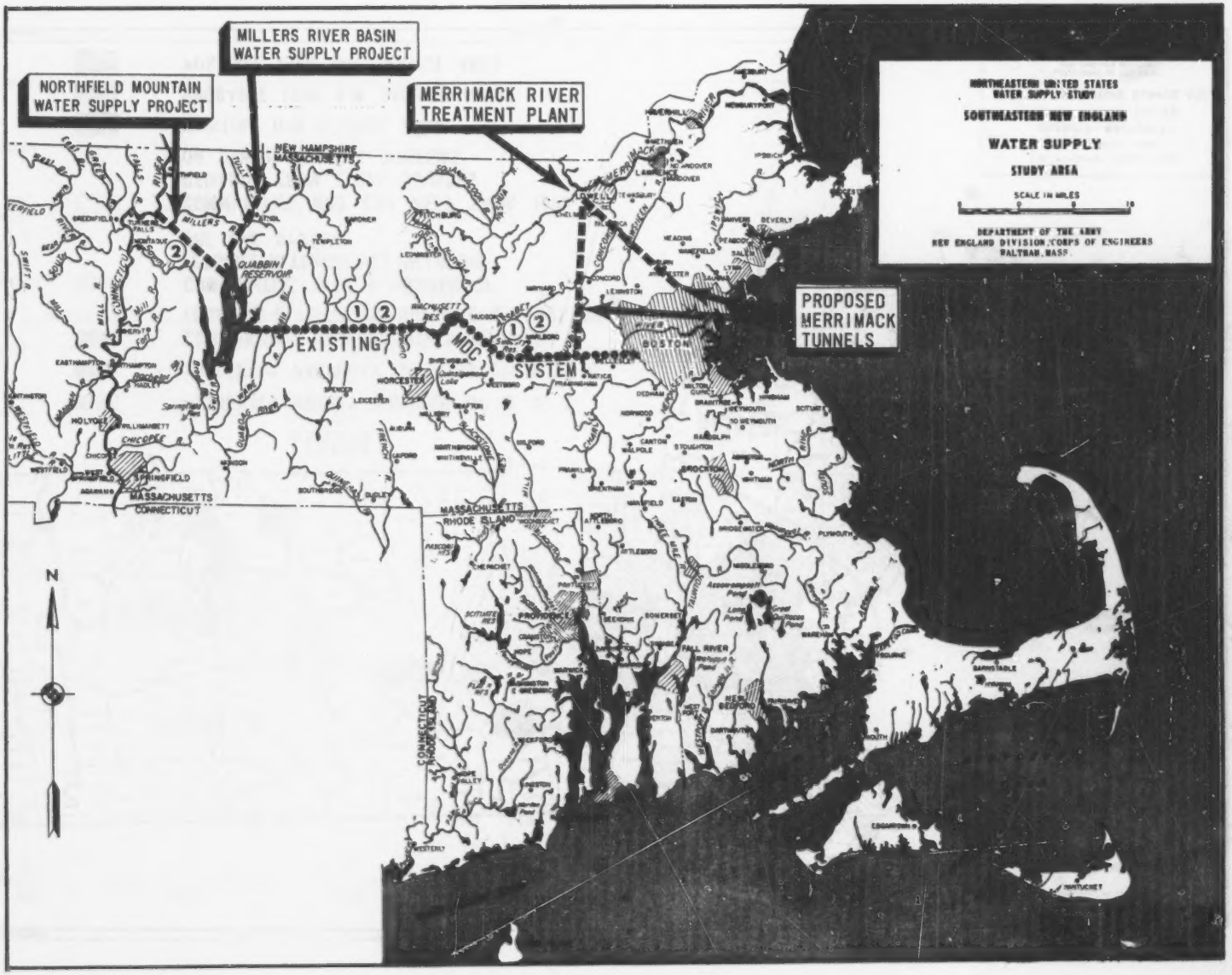
The information contained herein reflects a preliminary assessment of the physical and biological characteristics of each donor and receiver system and the potentially affected resources based on existing knowledge. Some specific details on the probable effect identified for each proposal are still unknown. In addition to public review of each proposed diversion project, a thorough analysis will also be completed by various Federal, State, and local agencies.

The Preliminary Environmental Assessment, which was distributed at the Late Stage Public Meetings, together with detailed environmental data compiled by contracted consulting firms, and information and comments gained at the public meetings, provided the basis for the preliminary draft Environmental Impact Statement for the proposed diversion projects.

In November 1972, copies of the preliminary draft environmental impact statement were furnished to more than 250 Federal, State, and local and private agencies and organizations. With the end of the review period on 23 December 1972, approximately 40 agencies had responded raising some 200 questions. All correspondence received is found in Section 8 of this Final Environmental Statement.



June 1969-US Army, Corps of Engineers


MILLERS RIVER BASIN
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NORTHFIELD MOUNTAIN
WATER SUPPLY PROJECT
MERRIMACK RIVER
TREATMENT PLANT
NEW HAMPSHIRE
MASSACHUSETTS
QUABBIN
RESERVOIR
EXISTING
MDC
SYSTEM
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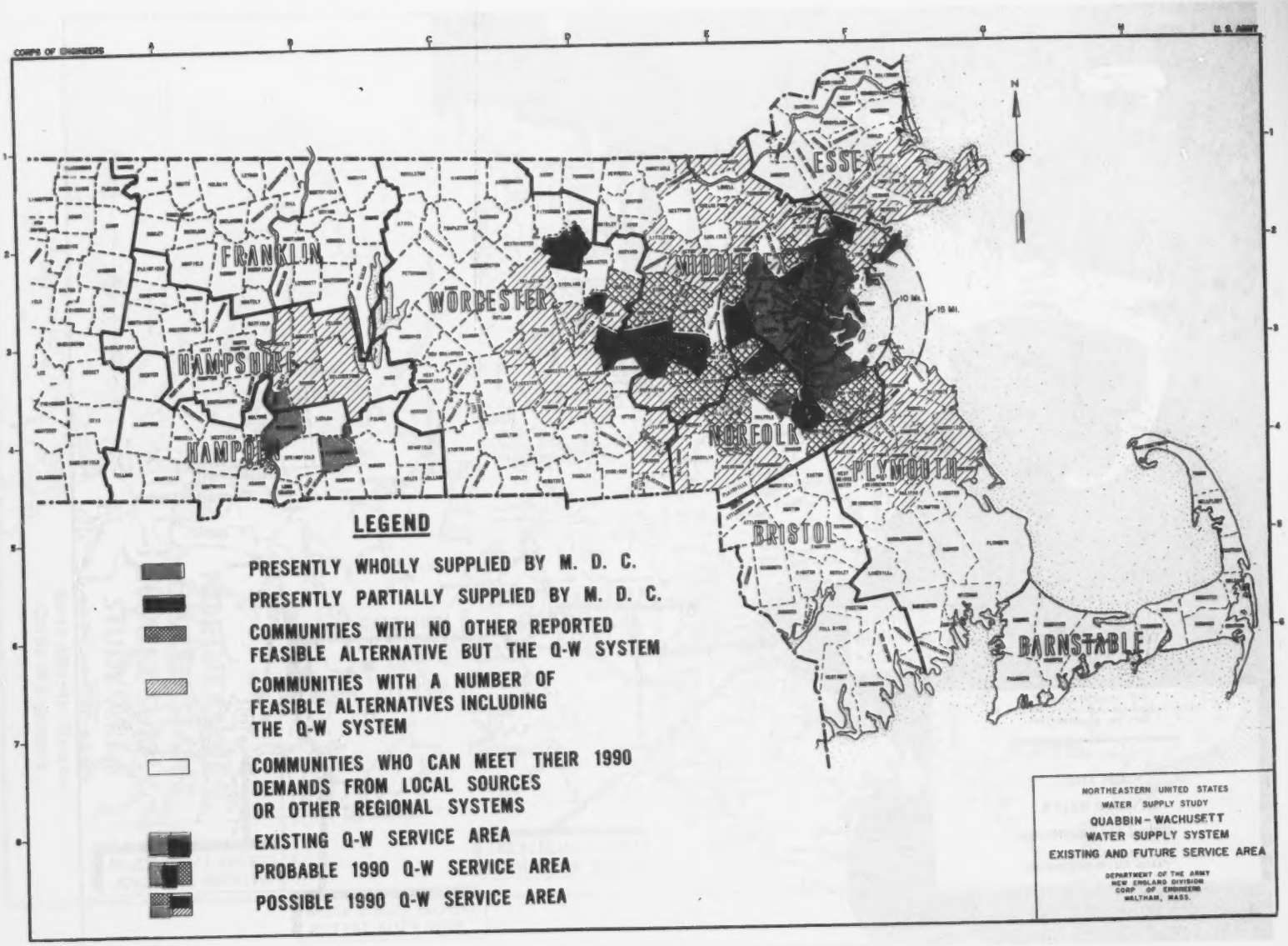
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COMMUNITIES WHO CAN MEET THEIR 1990 DEMANDS FROM LOCAL SOURCES OR OTHER REGIONAL SYSTEMS
EXISTING Q-W SERVICE AREA
PROBABLE 1990 Q-W SERVICE AREA
POSSIBLE 1990 Q-W SERVICE AREA
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
QUABBIN - WACHUSETT
WATER SUPPLY SYSTEM
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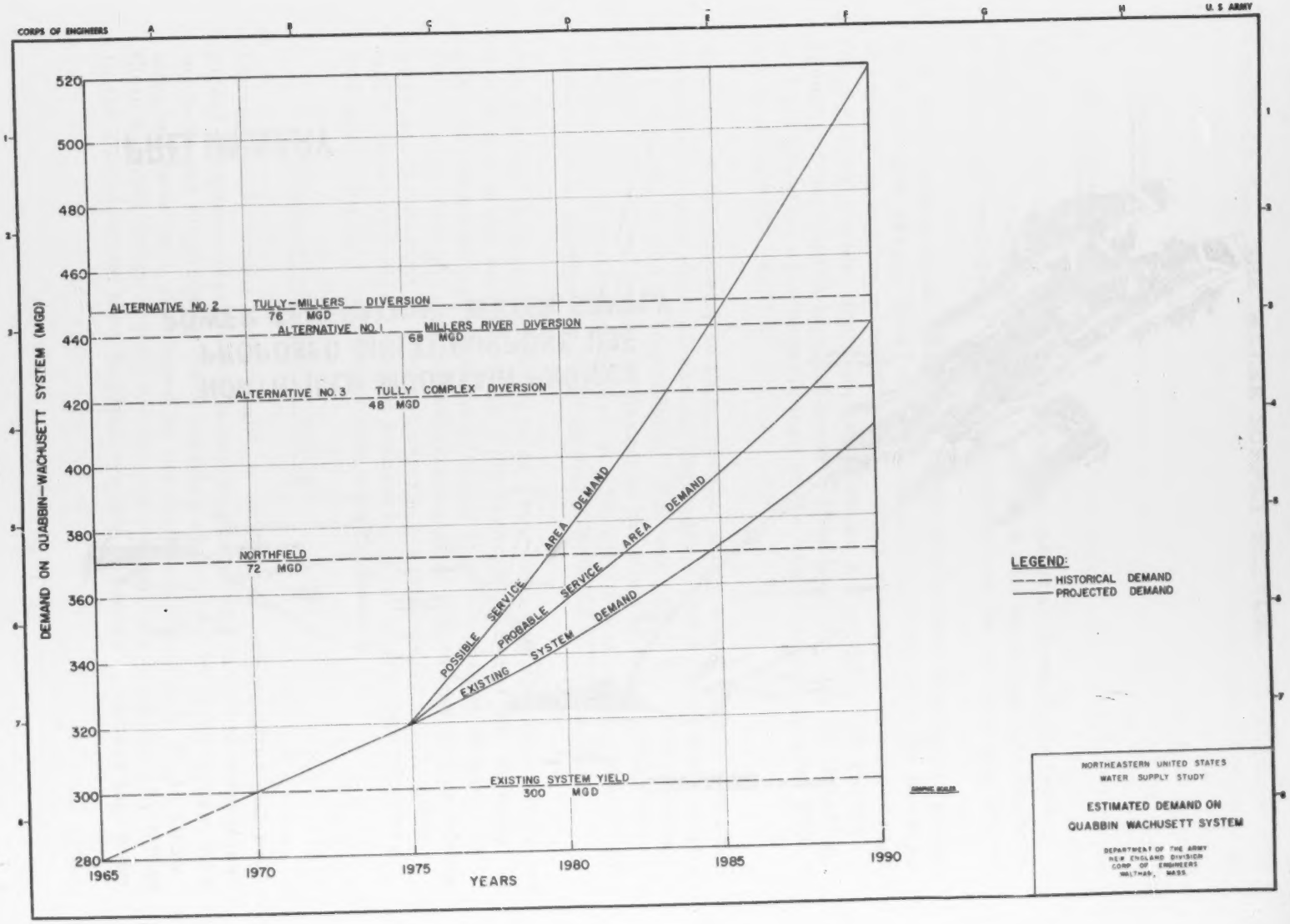
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DEMAND ON QUABBIN-WACHUSETT SYSTEM (MGD)
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YEARS
ALTERNATIVE NO. 2 TULLY-MILLERS DIVERSION 76 MGD
ALTERNATIVE NO. 1 MILLERS RIVER DIVERSION 68 MGD
ALTERNATIVE NO. 3 TULLY COMPLEX DIVERSION 48 MGD
NORTHFIELD 72 MGD
EXISTING SYSTEM YIELD 300 MGD
POSSIBLE SERVICE AREA DEMAND
PROBABLE SERVICE AREA DEMAND
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HISTORICAL DEMAND
PROJECTED DEMAND
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ESTIMATED DEMAND ON QUABBIN WACHUSETT SYSTEM
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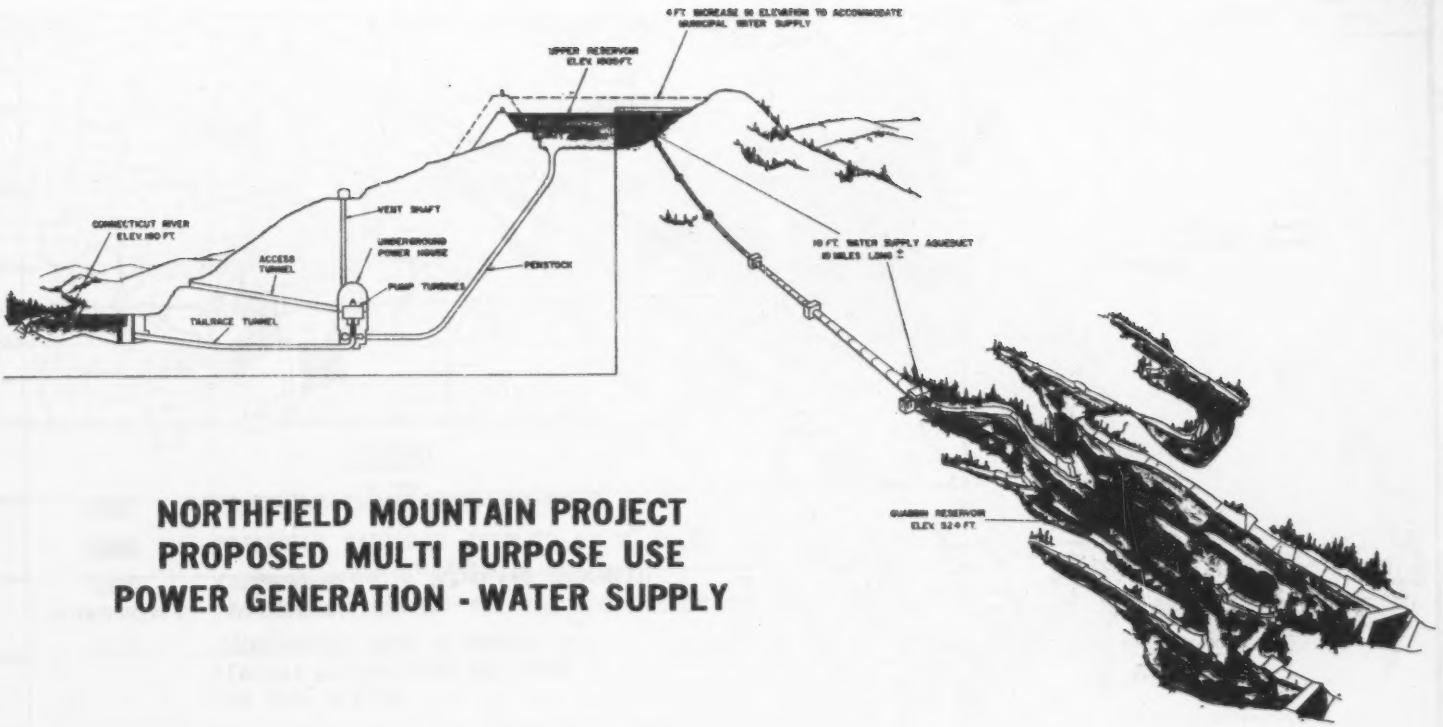

NORTHFIELD MOUNTAIN PROJECT
PROPOSED MULTI PURPOSE USE
POWER GENERATION - WATER SUPPLY

PRELIMINARY

THE WATER SUPPLY SETTING

General

A. Sixties Drought

As recognized in the NEWS Legislation, natural departures from normal precipitation and runoff conditions can have regional impacts on the social well-being of a large segment of the nation's population.

The long-term normal rainfall in southeastern New England is about 42 inches per year. This "normal" condition is actually the average of many high and low rainfall years. When rainfall is below average for a period of time, the area experiences a drought. The recent drought of the sixties in southeastern New England, for its duration, was the greatest ever experienced in the region based on over 200 years of rainfall record.

Because of the severity of this drought, many water supply systems were required to re-evaluate the dependable yield which their facilities could be relied on to produce. For example, the Metropolitan District Commission which, based on previous drought conditions, had estimated available sources at 330 million gallons per day (mgd) revised their dependable yield figure downward to 300 mgd.

The sixties' drought which began in 1961 when precipitation and water levels fell below normal, ultimately through its duration, directly affected the water use patterns of more than 20 million people. In 1965 alone, drought related water shortages and associated problems were severe enough to warrant emergency actions by local, state and Federal agencies. Within Massachusetts, more than 50 cities and towns imposed restrictions on water use.

B. Water Supply Agency Action

During and following the drought, a number of communities and regional planning agencies conducted engineering studies to determine methods for augmenting their existing supplies. In many cases, new supplies have been developed by the communities which would allow them to meet future supply needs. Investigations conducted by NEWS in the southeastern New England region, however, indicate that even

with the actions undertaken by local authorities, additional supplies must be made available.

It is anticipated that as water requirements increase and local water resources are fully developed, particularly in urban areas, many municipal systems will likely join some of the major systems, such as the Metropolitan District Commission (MDC) and increase the regional character of these systems. A description of the MDC system is given in the following paragraphs.

Existing Regional System - Metropolitan District Commission - (Boston)

The Metropolitan District Commission (Boston) is the largest regional system within New England. At present, this system supplies either wholly or partially the water supply needs of 42 communities within the Commonwealth of Massachusetts. Consumers of the serviced population number about two million or fully 37 percent of the Commonwealth's 1970 population.

Existing dependable yield of the system is estimated to be 300 mgd. Average daily water consumption furnished by the system in 1971 was 322 million gallons per day (thus the system is outstripping available supply) of which 273 mgd was delivered to municipalities which rely exclusively upon the MDC as their only supply source.

The MDC relies upon surface water as its supply source. Three major reservoirs: Quabbin, Wachusett and Sudbury impound flow from tributaries of both the Connecticut and Merrimack River Basins.

The Quabbin Reservoir, located in the center of Worcester County, is the backbone of the MDC system. It impounds the runoff from 186 square miles of the Swift River Watershed and flow diverted from 98 square miles of the Ware River Watershed, both tributaries of the Connecticut River. It has a capacity of 412 billion gallons at full reservoir elevation and is approximately 18 miles long.

The water from Quabbin Reservoir flows through the Quabbin Aqueduct for a distance of 24.6 miles to the upper end of Wachusett Reservoir in West Boylston. This aqueduct, which is "horseshoe" shaped, is excavated through solid rock and line with concrete. Provisions have been made at the Ware River Intake Works at Coldbrook to divert the

flood flows from approximately 98 square miles of the Ware River Watershed into the aqueduct for storage in either the Quabbin Reservoir or the Wachusett Reservoir. Under ordinary circumstances, the water is diverted directly to the Quabbin Reservoir for storage and then is drawn back into the Wachusett Reservoir as occasion requires.

The Wachusett Reservoir on the Nashua River, a tributary of the Merrimack River, above Clinton, was the principal reservoir of the MDC system prior to the construction of Quabbin Reservoir. It has a watershed of 107.7 square miles and a capacity of 65 billion gallons. It is approximately 8.4 miles long with a surface area of 6.5 square miles.

The water has two means of conveyance from Wachusett Reservoir -- the Wachusett Aqueduct and the recently completed Wachusett - Marlborough tunnel. The Wachusett Aqueduct consists of a rock tunnel section 2 miles in length, a brick and masonry conduit, "horseshoe" shaped, 7 miles in length and an open channel section of 20 feet wide at the bottom and 3 miles in length. The open channel section terminates in the Sudbury Reservoir in Southborough.

The major portion of the water supplied by the Wachusett Aqueduct is diverted at a diversion dam on the open channel section of the aqueduct in Marlborough into the Hultman Aqueduct. The remaining water flows into the Sudbury Reservoir.

The Sudbury Reservoir is situated on the north branch of the Sudbury River and impounds the runoff of approximately 22 square miles of watershed; has a storage capacity of approximately 7 billion gallons.

During summer months, large quantities of water flow from this reservoir through the Sudbury Aqueduct to the Chestnut Hill Reservoir in Brighton. From there, it is pumped into the distribution system.

The new Wachusett-Marlborough Aqueduct is a deep rock concrete lined tunnel, 8.0 miles long. It extends from the Wachusett Reservoir to the Hultman Aqueduct intake structure. The major portion of the water supply requirements of the Metropolitan Water District is delivered through this aqueduct to the Hultman Aqueduct and thence to the Norumbega and Weston distribution reservoirs.

The Hultman Aqueduct begins at the previously mentioned diversion dam located on the open channel section of the Wachusett Aqueduct. It extends from this point 22.7 miles in an easterly direction to the Chestnut Hill Reservoir and pumping stations. This aqueduct consists of cut and cover concrete conduit and a section of hardrock tunnel. At the

Sudbury Dam, it is interconnected to the Weston Aqueduct which is a cut and cover conduit extending to the low pressure service Weston Reservoir.

From an intake shaft at Norumbega, the City tunnel runs a distance of approximately 5 miles to a point in the vicinity of the Chestnut Hill Reservoir in Boston, where it is connected directly to several large distribution mains which convey the water to several of the communities serviced by the Low Service, Southern High and Southern Extra High distribution systems. The City tunnel, reduced from 12 feet to 10 feet in diameter, extends from Chestnut Hill Reservoir, a distance of approximately 7 miles, to a point in Malden, where it is connected directly into large distribution mains which convey the water to other communities serviced by the Low Service and Northern High Service distribution systems. Presently, construction of an additional deep rock tunnel, extending from Chestnut Hill Reservoir in Boston to a point in the vicinity of the Boston-Milton town line at Dorchester Lower Mills, is under way. The completed construction of this tunnel will enable the Commission to improve pressures in its Southern High Service distribution system.

The Chicopee Valley Aqueduct, consisting of 36 and 48 inch pipe, conveys water from the Quabbin Reservoir to the town of Wilbraham, South Hadley Fire District No. 1, and the city of Chicopee, extends from the outlet works of Winsor Dam to the Keating Hill Standpipe of the city of Chicopee.

Water supplied to consumers in the Metropolitan Water District is treated with small amounts of chlorine and ammonia as it enters the distribution system. Occasionally it is necessary to treat some of the storage and distribution reservoirs with small amounts of copper sulphate in order to combat algae growths which materialize from time to time. The Water Division of the Metropolitan District Commission maintains three laboratories, one at the Quabbin Reservoir, another in Framingham, and a third in Boston.

Pertinent data on the three major source reservoirs is shown in the following table:

TABLE 1

METROPOLITAN DISTRICT COMMISSION
SYSTEM SOURCES

	Location	Drainage Area Sq. Mi.	Storage Capacity (mg)
Sudbury:	Southborough Marlborough	22.0	7,000
Wachusett:	West Boylston Sterling Clinton Boylston	107.7	65,000
Quabbin:	New Salem Petersham Hardwick Ware Belchertown	284.8 [1]	412,000
	TOTAL	414.5	484,000

[1] Includes 96.8 square miles of Ware River Watershed

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Local Resource Potential

A. General

In estimating needs which might be required of the existing regional supply system (MDC), the role which locally available resources might play was investigated. The majority of new communities reported in this study as requiring connection to the regional system to meet future needs was the result of engineering studies[1] conducted by the Metropolitan Area Planning Council (MAPC). The MAPC comprises 98 municipalities in the Boston Metropolitan Region which include the majority of presently serviced MDC communities and the MDC's future short-range customers. In the following paragraphs, a brief summary of the MAPC engineering studies pertaining to local resource potential development is given.

"The purpose of this study is to identify and evaluate alternative water supply systems which may be developed to satisfy the water supply demands of the communities in the Council District through the year 1990. These systems would supplement the existing and potential local supply systems. The need for supplementing the existing supplies of most of the communities within the District was concluded from investigations conducted in conjunction with the 1969 Needs and Proposals report.

These investigations indicated that, of the 98 communities in the Council, only two communities had existing supplies capable of meeting projected 1990 demands, and only 17 communities outside of the communities served by the Metropolitan District Commission (MDC) reported potential supplies which, together with the existing supplies, could meet the 1990 demands.

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[1] Inventory of Water and Sewer Facilities, May 1967, Metropolitan Area Planning Council and Massachusetts Department of Commerce and Development, by Camp, Dresser & McKee, Consulting Engineers.

Projected Needs and Current Proposals for Water and Sewer Facilities, July 1969, Metropolitan Area Planning Council, by Camp, Dresser & McKee, Consulting Engineers.

Alternative Regional Water Supply Systems for the Boston Metropolitan Area, February 1971, Metropolitan Area Planning Council, by Camp, Dresser & McKee, Consulting Engineers.

The supplemental water systems discussed were developed along criteria and design guidelines chosen to be sufficiently generalized to permit use throughout the District, yet detailed enough to produce systems which were technically sound. The efficient development of a water supply system to meet the projected demands of the communities within the Council District will require further detailed studies of the most favorable alternatives presented in this study. All systems were developed without regard to institutional constraints. Particular emphasis was placed on the development of subdistrict systems which would serve a portion of the Council District through the utilization of local resources.

Five individual subdistricts were established as follows: the Charles River Subdistrict, the Concord River Subdistrict, the Ipswich River Subdistrict, the Neponset River Subdistrict, and the North River Subdistrict.

The supplemental needs of the individual communities were determined by comparing projected demands with the estimated safe yield of the existing and potential community supplies. Needs were assessed in accordance with the study policy that all local potential supplies were to be developed.

The needs may change in time as additional potential local supplies are discovered, or potential supplies must be abandoned.

It is emphasized that all potential groundwater sources must be fully explored, and development seriously considered even though the water is of quality that will require treatment.

B. Subdistrict Water Systems

The majority of the supplies to be developed to supply the subdistrict system will be surface supplies with either on or off stream reservoirs. It is imperative that before any of these alternatives are adopted, studies be conducted to investigate fully the environmental implications of these diversions.

1) Ipswich River Subdistrict: Two of the communities listed below have adequate existing supplies to meet their projected 1990 demands. An additional six communities have potential supplies which could adequately supplement their existing supplies through 1990. However, the potential supplies in five of the communities and the existing supplies in one of the communities make use of the Ipswich River.

Beverly	Ipswich	Reading
Boxford*	Lynn	Rockport
Danvers	Lynnfield	Rowley*
Essex	Manchester	Salem
Georgetown*	Middleton	Topsfield
Gloucester	North Reading	Wenham
Hamilton	Peabody	Wilmington

*Not in Council District

The Ipswich River does not have the capacity to meet these collective demands. Unless the Ipswich River is supplemented, it will be unable to supply sufficient additional yield to even the communities which now pump from it. Through the construction of three new off-stream reservoirs, together with a diversion system from the Merrimack River, the Ipswich River can be developed to adequately supplement the existing and potential supplies of the communities in the Ipswich River Subdistrict. The Merrimack River is the only possible source which would permit diversion to the Ipswich during dry periods, thus reducing the size of the off-stream reservoirs required. The longer the period of diversion, the smaller the size of the reservoirs required to produce the same yield. Under present conditions, the diversion works would be located above the City of Lowell in the Town of Tyngsborough with water being transmitted about 17.6 miles to Lubber Brook in Wilmington, a tributary of the Ipswich. If the quality of the water in the Merrimack River was upgraded, the diversion works could be moved downstream to Andover, thus decreasing the length of the raw water transmission main.

Diversions would then be made from the Ipswich River at three general locations. At the first location, diversions would be made to a proposed 1800 million gallon (mg) regional reservoir in Lynnfield and to the existing Lynn and Peabody Reservoirs. The second diversion would occur downstream off Route 1 in Topsfield and would supply the proposed 1800 mg Topsfield reservoir. This new reservoir would be operated in conjunction with the existing facilities of the Salem and Beverly Water Supply Board. The third diversion would be located in Ipswich. Water would be pumped to the proposed 2800 mg Ipswich Reservoir.

2) Concord River Subdistrict: None of the MAPC communities in this subdistrict will be able to adequately meet their projected 1990 demands. However, the communities in the Concord River Subdistrict

can also be supplied by the Merrimack River. This subdistrict includes four MAPC communities, Acton, Bedford, Concord and Littleton, and 13 communities adjacent to the Council District.

These communities would take their supply at the same location as the diversion works proposed for the Ipswich River Subdistrict mentioned above. The two pumping facilities may, in fact, be combined. If, however, both subdistrict systems are developed, it may be necessary to develop either additional storage facilities or a special working schedule to eliminate combined diverting during short periods of extreme low flows and thereby degrading water quality. The need will depend to a large degree on the number of the communities outside the MAPC District which would be supplied by the Concord River Subdistrict system.

3) Charles River Subdistrict: The third subdistrict considered includes the 17 communities in or adjacent to the Charles River watershed and listed below:

Bellingham	Milford	Walpole
Dover	Millis	Wayland
Franklin	Natick	Wellesley
Holliston	Norfolk	Westwood
Medfield	Sherborn	Wrentham
Medway	Sudbury	

Five of these communities can develop potential supplies to adequately meet their projected 1990 demands. The communities in this subdistrict have been subdivided into two groups, the Upper and the Middle Charles River Groups. By developing the abundant potential local supplies of Franklin and Milford and interconnecting the individual systems, the six communities in the Upper Charles River Group can adequately meet their projected 1990 demands. The 11 communities in the Middle Charles River Group can extend the adequacy of their systems by grouping together similar to the Upper Charles River Group.

However, unless the MDC is extended to supply Sudbury, Medfield, Norfolk and Dedham, the combined 1990 demands cannot be met even if all potential supplies are developed. Following the completion of the MAPC study, the NEWS study requested the opinion of the U. S. Geological Survey (USGS) concerning the hydraulic relationship of the well field proposed for the Middle Charles River Group and the River. The USGS replied they felt the proposed well fields were directly linked to the nearby river. With such a link, the well field in essence would be drawing from river flow, particularly in low flow periods. Low flow

conditions in the Charles River at present are a critical factor in the river's water quality. It was felt that any substantial decrease in flow caused by withdrawals for water supply would increase water quality problems. Thus, the NEWS study proposed communities listed as middle Charles to be served by connection to the regional system.

4) Neponset River Subdistrict: Only the town of Sharon in this subdistrict, consisting of Avon, Foxborough, Sharon and Stoughton, can develop supply adequate through 1990. The remaining three subdistrict communities will require an outside supplementing source of supply. The projected 1990 demand of the Neponset River Subdistrict can be adequately met through the development of Ponkapoag Pond as a water supply reservoir. By raising the level of the Pond some 19 feet, adequate storage capacity can be provided to receive flood flows pumped from the Neponset River. Water would be pumped from the Neponset River only during periods when the flow exceeds 25 cubic feet per second (cfs). During dry periods, pumping will be permitted only over a few months of the year. In order to provide sufficient yield, it will be necessary to provide pumping capacity greatly in excess of the estimated safe yield of the system.

5) North River Subdistrict: The fifth subdistrict system investigated would provide supplemental supply to communities located south and southeast of Boston. This North River Subdistrict includes the 15 communities located in the MAPC District, listed below, plus the communities in the Old Colony Planning Council.

Braintree	Holbrook	Randolph
Cohasset	Hull	Rockland
Duxbury	Marshfield	Scituate
Hanover	Norwell	Stoughton
Hingham	Pembroke	Weymouth

Cohasset is the only member community which can develop supplies adequate through 1990. However, providing all of the communities develop their potential supplies, the North River could be developed to supply all of the communities in the subdistrict well beyond the year 1990 with the exception of the towns of Braintree, Weymouth, Randolph and Holbrook. While these communities could be supplied by the North River, it would be more realistic to supplement the supplies of these communities from the MDC, since they are remote from the North River, near the existing MDC system, and their demands would decrease the North River's period of adequacy. The only source that will be

available to supplement the North River once the demands exceed its yield is the MDC, and these four communities would have to be connected to the MDC eventually.

Development of the North River for water supply purposes will require the construction of an on-stream storage reservoir located in the present tidal reach of the North River, a water treatment plant, and pumping and transmission facilities. It is recognized that an impoundment within the tidal reaches of the North River will affect the ecology of the estuary. Early estuarine studies should be made to determine the implications of ecological changes."

6) Summary: Certain groups of communities (particularly those outside Metropolitan Boston) can satisfy their present and projected 1990 needs without relying directly on the MDC. However, they cannot do so unless the MDC supplies certain key communities such as Sudbury, Medfield, Norfolk, Dedham, Braintree, Weymouth, Randolph and Holbrook. It, therefore, becomes apparent that any concept of regional supply for the eastern Massachusetts - Rhode Island Study Area depends on firming up the existing regional system, i.e. the MDC. This is the specific problem addressed by the present survey report.

Also by 1990, many communities not served by the MDC will collectively require water in addition to that available in their immediate watersheds. The development of institutions and physical systems to meet with this regional problem is critical. By 2020, the MDC will also require additional water from a large regional source. These two problems are the subjects of on-going studies.

Expected Expansion of the Regional System Service Area

Because potential new water supply sources within the Eastern Massachusetts area are rapidly becoming exhausted, communities are forced to look to regional concepts in water resource development as a means of meeting their future water supply needs. The MDC system represents the largest system in Massachusetts, and for this reason is expected to be called upon to expand its service area considerably by the year 1990.

Under present Massachusetts state Legislation, the MDC system is required to permit any municipality within 10 miles of the State House in Boston to become a member upon application. The MDC is further bound by the same legislation to allow any other municipality within 15 miles of the State House which could be reasonably serviced by the MDC to become, upon application, a member. Any non-member municipality with the approval of the Massachusetts Department of Public Health can be furnished water by the MDC.

In an attempt to determine what communities might be serviced by the regional system in 1990, four groups of municipalities were identified.

1) Cities and towns presently serviced by the MDC.

2) Municipalities who cannot meet their future demands from local sources and who have no other reported feasible alternative but to join the MDC system.

3) Communities with a number of reported feasible alternatives including joining the MDC system.

4) Those cities and towns who can meet their future demands from local sources or from other regional systems not including the MDC system.

The MDC system presently is made up of 32 member communities, 25 of which are wholly served. The MDC also supplies water to 10 non-member communities which draw from either the Chicopee Aqueduct in the Springfield area or from the Wachusett-Sudbury reservoir system. These cities and towns, listed in Table 2, obtain water from the MDC because there simply are no other feasible sources of water supply available to them. Therefore, with the exception of Peabody, it has been assumed that all additional future water demands originating from

these communities will be met completely by the MDC system. Peabody's additional demand may be met by further development of the Ipswich River.

The remaining communities in the study area were then investigated to determine if they can meet their 1990 water demand locally and then, if not, whether it is feasible for them to join the MDC system. The communities listed in Table 10 have no other reported feasible alternative to meet their additional future water demands other than joining the MDC system. Because they all can be reasonably served by the MDC, these cities and towns are included in the potential 1990 service area.

The third category of communities are listed in Table 4. These cities and towns have a number of feasible alternatives including connection to the MDC system. Other alternatives available to the municipalities include development of the Merrimack, Ipswich and North Rivers as well as ground water resources in some cases.

Those communities not anticipated to join the MDC system by 1990 are shown on Table 4. Based on a review of these municipalities' 1990 water supply needs, it appears adequate local resource is available or entrance to another regional system is a more feasible solution.

The 1990 water demands on the Quabbin - Wachusett Reservoirs (MDC system) were then estimated for the three groups of communities which may be serviced. Supply demand estimates, as described in Table 4, were derived using both population and industrial output forecasts. Population increases were combined with estimates of future per capita usage to provide supply needs domestic, commercial and public usage. Industrial output forecasts using a water use per dollar output analysis allowed the estimation of supply needs for heavy water using industry. Both estimates were then combined to give total future water requirements.

Once the supply requirements were established, the additional development necessary to meet these needs was determined. This was accomplished by subtracting safe yields of existing and anticipated supply sources from the total estimated needs. Using this methodology, the existing MDC's service area 1990 water demand was estimated to be about 410 million gallons per day (mgd). If the cities and towns with no other reported alternative were to join the MDC, total demand for 1990 was estimated to be about 441 mgd. If all communities noted as including the MDC as an alternative source were serviced, then 519 mgd would be needed in 1990.

Based on the investigations conducted in this report then the 1990 water supply needs to be met by the MDC could vary from a minimum of 410 mgd to a possible maximum of about 519 mgd. Although it is possible that all communities described as having other potential sources may elect to join the MDC system, it is unlikely. Based on efforts observed by this group, it appears that certain communities are willing and planning to develop the local resource to meet their needs. Providing additional supplies to non-MDC communities is part of the problem addressed by on-going NEWS studies. In this report, 1990 demands on the regional system estimated for presently served communities and those with no other reported option were used for planning purposes.

TABLE 2

COMMUNITIES PRESENTLY BEING SERVICED BY THE M.D.C.

FULLY SUPPLIED MEMBERS:

Arlington	Malden	Quincy
Belmont	Marblehead	Revere
Boston	Medford	Saugus
Brookline	Melrose	Somerville
Chelsea	Milton	Stoneham
Everett	Nahant	Swampscott
Lexington	Newton	Waltham
Lynnfield Water District	Norwood	Watertown
		Winthrop

PARTIALLY SUPPLIED MEMBERS:

Cambridge	Peabody
Canton	Wakefield
Needham	Weston
	Winchester

NON-MEMBERS SUPPLIED:

Clinton	Leominster	Southborough
Chicopee	Marlborough	South Hadley, F.D. #1
Framingham	Northborough	Wilbraham
		Worcester [1]

Total Estimated 1990 Demand	450 MGD
1965 Safe Yield [2]	335 MGD
Anticipated Expansion of Local Sources	5 MGD
1990 Deficit	110 MGD

[1] On an emergency basis only.

[2] Includes 300 MGD Safe Yield of Quabbin-Wachusett System.

TABLE 3

COMMUNITIES WITH NO OTHER REPORTED OPTION

Ashland	Millis
Avon	Natick
Bolton	Norfolk
Braintree	Randolph
Dedham	Sherborn
Dover	Stoughton
Holbrook	Stow
Holliston	Sudbury
Hudson	Wellesley
Lincoln	Westwood
Maynard	Weymouth
Medfield	Woburn

Total Estimated 1990 Demand	74 MGD
1965 Safe Yield	39 MGD
Potential Local Sources	4 MGD
1990 Deficit	31 MGD

TABLE 4

COMMUNITIES WITH OTHER OPTIONS INCLUDING THE M.D.C. SYSTEM

IPSWICH RIVER:

Beverly	Ipswich	Peabody
Danvers	Lynn	Reading
Essex	Lynnfield	Rockport
Gloucester	Middleton	Salem
Hamilton	North Reading	Topsfield
		Wilmington

Estimated 1990 Demand	58 MGD
1965 Safe Yield	47 MGD
1990 Deficit	11 MGD

CONCORD RIVER:

Acton	Concord
Bedford	Littleton

Estimated 1990 Demand	12 MGD
1965 Safe Yield	5 MGD
1990 Deficit	7 MGD

MERRIMACK RIVER:

Billerica	Dracut
Chelmsford	Tewksbury
	Tyngsborough

Estimated 1990 Demand	22 MGD
1965 Safe Yield	12 MGD
1990 Deficit	10 MGD

TABLE 4 (cont'd)

NORTH RIVER:

Abington	Hanson	Pembroke
Brockton	Hingham	Rockland
Duxbury	Hull	Scituate
Halifax	Marshfield	Whitman
Hanover	Norwell	

Estimated 1990 Demand	39 MGD
1965 Safe Yield	28 MGD
1990 Deficit	11 MGD

CHARLES RIVER:

Bellingham	Medway
Foxborough	Wrentham

Estimated 1990 Demand	9 MGD
1965 Safe Yield	5 MGD
1990 Deficit	4 MGD

MILL RIVER:

Hopedale	Mendon
Hopkington	Milford

Estimated 1990 Demand	6 MGD
1965 Safe Yield	2 MGD
1990 Deficit	4 MGD

TABLE 4 (cont'd)

WORCESTER AREA:

Auburn	Holden	Princeton
Berlin	Leicester	Shrewsbury
Boylston	Millbury	West Boylston
Grafton	Paxton	Worcester

Estimated 1990 Demand	47 MGD
1965 Safe Yield	26 MGD
1990 Deficit	21 MGD

COLLEGE AREA:

Amherst	Hadley
Belchertown	Pelham
Granby	South Hadley, F. D. #2

Estimated 1990 Demand	10 MGD
1965 Safe Yield	4 MGD
1990 Deficit	6 MGD

WEST SPRINGFIELD:

Estimated 1990 Demand	7 MGD
1965 Safe Yield	3 MGD
1990 Deficit	4 MGD

TOTAL ESTIMATED 1990 DEMAND	210 MGD
TOTAL 1965 SAFE YIELD	132 MGD
TOTAL 1990 DEFICIT [1]	78 MGD

[1] Deficit shown is expected to be met by local resource development.

Capability of System to Meet Future Needs

A. Source

The estimated yield from the existing MDC sources of supply is about 300 mgd. In 1971, the average daily demand of all communities serviced by the system was about 3[illegible]2 mgd. At present then, withdrawals from the system exceed the available dependable yield. The most striking example of this demand in excess of supply situation is at Quabbin Reservoir, the main storage facility of the system. From a low pool elevation of 495 feet (full pool 530 feet) the reservoir has been unable to replenish its storage.

Forecast demands on the system for 1990 indicate an additional increment of 141 mgd of yield will be necessary unless water use practices of the serviced population are altered dramatically.

The MDC as a result of their analysis have reported to the Massachusetts State Legislature the next step in providing the supply necessary to meet future needs is the diversion via the Northfield Mountain [1] Project. At a NEWS meeting held in Boston, Massachusetts, in May 1970, local, State and Federal officials agreed that the Northfield Mountain Project was a viable element in any regional water supply plan.

If the yield from Northfield Mountain is made available, the total dependable yield available to the system would be about 372 mgd. Based on the forecast demands, this project would meet supply needs to about 1984. In order to meet the short-range 1990 needs then an additional source of supply will be needed.

In the report, the potential of diverting water from the Millers River Basin, a tributary of the Connecticut, is being investigated. Depending on the method of development employed, this source could produce from 48 to 76 mgd of additional supply.

Development of the Millers River Basin Project as described in the report then could add about 25 percent to the existing system yield. This addition, when combined with the Northfield Mountain yield, would allow adequate supplies within the serviced communities to about 1990.

B. Transmission Facilities

Although the intent of this Interim Report of Survey was to investigate new sources of supply to meet future needs, a preliminary analysis of the MDC's transmission facility was also conducted. The purpose of

[1] Subject of a companion NEWS report.

evaluating the transmission facilities was not to include any needed improvements as recommendations for authorization, but rather to present a full picture of the system's present capability.

In order to determine the adequacy of the major transmission aqueducts, the peak demands for the system had to be estimated. Variations in water demands due to seasonal weather changes have always been important considerations in the design of water supply systems in the northeastern United States and particularly in New England. Historically, summer periods have promoted exceptionally high water demands which quite often last for several weeks. In most cases, these peak demands must be met by the water supply storage reservoirs, since storage within the distribution system itself cannot usually be economically constructed to handle these peak loads.

The ratio of the maximum day demand to the average daily demand is directly related to the type and character of the development within the community or communities to be served. The present MDC system, as described earlier, services 32 member communities within the greater Boston area. Twenty-five of the communities depend wholly upon the system to supply their water needs, while the remaining seven communities make maximum use of their own sources and only rely upon the MDC system to supply their peak demands. The 25 wholly supplied communities range from completely residential in character to the inner core cities with industrial and commercial development. During the recent drought of the 60's, the ratio of the maximum day demand to the average daily demand for the city of Boston reached a high of 1.24, while the ratio for the total 25 communities reached 1.65. This difference has been attributed to the effect of the suburban communities peak demands upon the system. If the MDC is called on to expand its service area, it will be adding suburban communities which are largely residential in nature. Thus, the maximum daily demand ratio can be expected to increase above the present high figure of 1.65. The amount of increase will, of course, depend on what portion of the total water demand upon the system the new members demand represents.

To determine what increase, if any, the transmission facilities would have to supply by 1990, peak demand characteristics of a number of eastern Massachusetts communities were examined. Based on this investigation, it appeared a maximum day ratio of 1.70 to average daily demand represented a reasonable value for planning purposes. A comparison of this figure to other historic and projected maximum day data for large metropolitan systems in the Northeastern United States was then made and proved to be comparable.

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Applying the maximum day ratio to demands forecast in the Boston Metropolitan area, it appears the present transmission facilities from Wachusett Reservoir to the Boston City tunnel system may be inadequate. This inadequacy can be primarily attributed to the limiting carrying capacity of the Hultman Aqueduct.

At present, the Metropolitan District Commission has under way a large scale (one million dollar) investigation of its water supply system. Included in this investigation will be an examination of the future courses of action which the MDC may pursue with regard to supply, demand and conveyance facilities. One of the major study elements will be the adequacy of the system's aqueducts. The results of this investigation will describe problem areas and corrective actions needed.

1. Project Description. Possible water supply diversion proposals under consideration and included in this Environmental Impact Statement are:

A. Diversion of Connecticut River water through the Northfield Mountain pumped storage project into Quabbin Reservoir.

B. Diversion of flow from the East Branch Tully and Millers Rivers into Quabbin Reservoir.

No known National Register properties would be affected by the projects.

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

Authorization for construction of the diversion facilities from Northfield Mountain to Quabbin Reservoir has been granted to the Metropolitan District Commission by the Massachusetts State Legislature. Recognizing this fact, the representatives of the Federal, State and local agencies and interests at the May 1970 meeting recommended that the Corps of Engineers investigate the project as a very viable element in any regional water supply plan for Southeastern New England. It was further recommended that the NEWS studies be designed to complement those under way, or planned by the Metropolitan District Commission.

The Northfield Mountain Diversion project as in the Millers River Basin Alternatives would use a high flow skimming technique; that is, flow would be diverted during high flow periods, principally during spring run-off periods. As a means of control, diversions would not occur if flow in the Connecticut River at Montague City U. S. Geological Survey gaging station is less than 17,000 cubic feet per second or about 11,000 million gallons per day. This control flow is specified in the current Massachusetts State Legislation regarding the Northfield Mountain project.

Description of the Facilities

In this project, water would be diverted from the Connecticut River through the Northfield Mountain pumped storage hydroelectric facility located in Northfield and Erving, Massachusetts.

The pumped storage project for electricity generation consists of a high level storage reservoir on Northfield Mountain, underground pump-turbine facilities and low level storage in the Turners Falls

pool. The high level reservoir consists of a system of dams and spillways to provide 17,000 acre-feet of storage about 800 feet above the Turners Falls pool on the Connecticut River.

In order to provide the water supply diversion volume, the electric utility would pump an additional 375 million gallons each day that control flows in the Connecticut River would allow. The additional yield which could be made available by this plan would be 84 million gallons per day on a long term average annual basis. Because of operational considerations, such as water quality testing, analysis, etc., however, the yield estimated to be made available to Quabbin Reservoir is about 72 million gallons per day.

In order to incorporate the water supply diversion into the Northfield Mountain Project, three modifications to the pumped storage facilities are necessary. These are:

1) Raising the upper reservoir located on Northfield Mountain about 4 feet to provide about 50,000,000 cubic feet of additional storage capacity.

2) Provision of head works at the upper reservoir for the diversion aqueduct to Quabbin Reservoir.

3) About 9.8 miles of connecting aqueduct and outlet facilities at Quabbin Reservoir.

The first two items necessary for diversion have been essentially completely constructed at the upper reservoir on Northfield Mountain by the electric utility construction forces. A plan of these facilities is shown in the attachment.

The third item necessary for water supply diversion is presently in preliminary design stages by engineers at the MDC. At present, plans indicate water would be diverted from the upper reservoir through an eight-foot diameter steel pipe constructed in the east dike of the Northfield Mountain upper reservoir. Water would be withdrawn at an average rate of 375 million gallons per day and delivered to an intake shaft of the Northfield - Quabbin tunnel aqueduct.

The intake down shaft would be a scroll type configuration with a diameter of 16 to 18 feet. Water would be conveyed from a maximum upper reservoir pool elevation of 1004 feet msl in this vertical shaft to the aqueduct at elevation 300 feet msl.

The aqueduct would be a 10-foot finished diameter tunnel with a reinforced concrete liner. From the downtake shaft, the aqueduct would run about 0.5 miles to the vicinity of the south bank of the Millers River. At the Millers, a 10-foot diameter construction shaft would be excavated.

Continuing to Quabbin, the aqueduct would be driven about 3.0 miles to the vicinity of Bullard Hill. In this tunnel reach, the aqueduct would rise from the 300' elevation at the Millers River to elevation 440'. A second construction shaft would be provided at this location.

From Shaft No. 3, the tunnel would continue about 6.2 miles to the uptake shaft located in Rattlesnake Hill adjacent to Quabbin Reservoir. At Rattlesnake Hill, an uptake shaft would be driven from elevation 440 to elevation 500. At elevation 500, the tunnel would be enlarged from ten to 30 feet in width in a 150 foot long transition zone. Flow entering Quabbin from the transition zone would be conveyed in a 30-foot wide channel cut to the main channel of the Middle Branch of the Swift River.

Cost estimates for the water supply element of the project, including the raising of the upper reservoir, intake works, connecting tunnel aqueduct to Quabbin Reservoir and outlet works, would total about 40 million dollars.

Preliminary estimates of land needed for this project total about 30 acres. Land requirements for this plan may also involve about 5 acres for disposal of rock excavated from the tunnel. The firm requirement for these lands, however, would be determined during detailed design.

A major element considered in the evaluation of this project was the impact which the diversion could have on the environmental health of Quabbin Reservoir. A description of these possible impacts is included in Section 3.

MILLERS RIVER BASIN WATER SUPPLY PROJECT

Three alternatives were developed all within the Millers River Basin to meet the water demands of the expanded regional system. The first is diversion directly from the Millers River above Athol to Quabbin Reservoir. This diversion would result in an average annual yield of 68 mgd and would require advanced treatment of the point sources of pollution on the Millers River, upstream of the diversion site. The second alternative is a combination of one and three. Water would be diverted only from the East Branch Tully River and from the Millers River above Athol, resulting in an average annual yield of 76 mgd. As in the first alternative, advance waste treatment of the pollution sources would be required; but because Tully Lake would not be used for water supply storage, the reservoir would not have to be stripped. Alternative three is the Tully Complex - a series of small diversion works on four tributaries of the Millers River. An average annual yield of 48 mgd is expected with no treatment required before entering Quabbin Reservoir.

On the basis of the investigations conducted, Alternative No. 2 is the preferred plan and is the project described in the following paragraphs. Alternative Nos. 1 and 3 are described in Section 5 - Alternatives to the Proposed Action.

In this plan, diversion from the Millers River Basin would be accomplished via withdrawals from the East Branch Tully River and the mainstem of the Millers River above Athol, Massachusetts. Facilities necessary for development would include a morning glory type inlet structure just downstream from the existing Tully flood control reservoir and an 8-foot diameter tunnel to the Millers River above Athol. At the Millers River, a second tunnel inlet would be constructed, connected to the Tully aqueduct, and from this location, a 10-foot tunnel would be driven to Quabbin Reservoir where water would be discharged through an outlet structure. Waste treatment plants on six point sources of pollution would also be required. The plate titled Tully - Millers Diversion - Alternative No. 2 shows the location of the proposed structures.

The Tully diversion site for this alternative is located at the existing Corps of Engineers flood control reservoir on the East Branch Tully River. However, no storage would be used for water supply within the flood control reservoir. The site is located about 4 miles upstream from the confluence of the Tully River and Millers River in Athol. The structure would consist of an inlet to the 8-foot diameter tunnel to the Millers River above Athol and an 8-foot high bascule gate attached to the existing Tully Lake outlet channel.

The existing outlet channel of Tully Lake would be enlarged to 30 feet wide for a distance of 1200 feet. A 30-foot long, eight-foot high gate would regulate the water height and velocity in the outlet channel. During diversion, the bascule gate and the three 8 x 8 foot gates would be raised creating a stilling pool and increasing the water level above the lip of the tunnel inlet. The 22-foot morning glory drop inlet would be located adjacent to the outlet channel in the middle of a 60-foot square chamber cut in rock. The three 8 x 8 foot gates to the inlet chamber would be opened only when diversions were occurring. By regulating these four gates and the gates at the existing dam, various combination of diversion flows and downstream flows can be achieved.

Water entering the morning glory inlet would drop down the vertical eight-foot shaft into the tunnel. The eight-foot diameter tunnel would cover a distance of 2.5 miles from the outlet of Tully Lake to a point upstream of Athol on the mainstem of the Millers River where it would then feed into the Miliers-Quabbin leg of the aqueduct. The tunnel would be excavated by mole methods and concrete lined to a finished diameter of eight feet.

The Millers River diversion site would be located on the Millers River about three miles upstream from the confluence of the Tully and Millers Rivers in Athol, Massachusetts. The structure located in Athol would consist of an inlet to the 10-foot diameter tunnel to Quabbin Reservoir controlled by a combination weir-bascule gate extending across the Millers River. The concrete control structure, 120 feet long, would provide a regulated pool for the inlet shaft. The bascule gate, 70 feet long and 5 feet high, would regulate the water height and velocity to the inlet. During diversion, the bascule gate would be raised creating a stilling pond and increasing the water level above the elevation of the inlet structure weir. The 22-foot diameter morning glory inlet tapering to the 10-foot diameter inlet shaft would be located on the northern bank in the center of a 60-foot square chamber cut in rock. The three 8 x 8 foot gates to the inlet chamber would be opened only when diversions were occurring. By regulating these gates in conjunction with the bascule gates, various combinations of diversion flows and downstream flows can be achieved.

Water diverted from the river would enter the morning glory inlet and drop down the 10-foot diameter vertical shaft into the tunnel and join the Tully River water. The 10-foot diameter tunnel would run a distance of 7 miles from the Millers River inlet to a point south of Gays Hill on Quabbin Reservoir. The tunnel would be excavated in

rock by mole methods and lined with concrete to a finished diameter of ten feet. Both the inlet and outlet shafts would be used as construction shafts. The outlet at Quabbin Reservoir would consist of an inclosed transition structure, a concrete stilling basin and a 20-foot wide trapezoidal channel leading to the Middle Branch of the Swift River in Quabbin Reservoir. The structure would be founded on bedrock and includes a wet well with two 8 x 8 foot gated passageways and a control building. The stilling basin would reduce velocities to a reasonable level if Quabbin Reservoir was below elevation 503 msl; but if the pool was higher, discharge would be directly into the pool. The riprapped channel would extend from the stilling basin some 800 feet across a swampy area to the original Middle Branch of the Swift River channel. This channel makes its way to Windsor Dam and the Quabbin - Wachusett tunnel inlet.

An analysis was made of the present and projected loadings of waste discharges upstream from the diversion intake, present and planned treatment, and present and planned waste effluents. Based on available information, further treatment beyond that presently planned would be required to insure a good quality water for diversion. Our studies indicate that tertiary treatment at the source of pollution is preferred to water treatment at the Millers River intake. The final determination of this additional treatment will be made during the Design Phase. By that time, the planned secondary treatment plants will probably be in operation and the effectiveness of these plants will be known. Also, then, the effect the existing sludge banks will have on the water quality can be measured. It is expected that once the load on the river is minimized, the natural flushing action will wash away large amounts of sludge in the Millers and Otter Rivers resulting in a relative stable water quality.

The operation of this diversion would depend first on the flow in the Connecticut River as measured at the U. S. G. S. gaging station at Montague City, Massachusetts; and secondiy, on the flow in the rivers at the two diversion sites. On any given day, the flow in the Connecticut River at Montague City would be checked to see if the flow is above 17,000 cfs. If it is not, then no diversion would occur no matter what the flow in the Millers or Tully Rivers is. If the flow in the Millers River at the diversion site is less than the flow determined to be required for the river and its environment, then no diversion from the Millers River would occur. This required flow, referred to as the control flow, which is an estimate, not permanently set and may have to be adjusted upon project implementation, was determined from flow requirements for assimilation of wastes; for fish and wildlife, and is related to the time of year and the drainage area.

TABLE 5

MILLERS RIVER CONTROL FLOW AT INTAKE

	Jan Feb Mar	Apr May Jun	Jul	Aug	Sep Oct Nov	Dec
CSM	0.5	1.25	2.0	1.0	0.75	0.5
CFS	100	250	400	200	150	100

If the Connecticut River flow is above 17,000 cfs and the Millers River flow is above the control flow for that day, then diversion from the Millers River would occur. In no case would water be diverted lowering the flow in the river below the control flow. But, neither would the flow be augmented when it was naturally below the control flow. So, the rate of diversion on any given day could vary from zero to the maximum capacity of the tunnel, 730 cfs.

The same procedure would apply for diversion of East Branch Tully River water, except the control flows and the maximum diversion rate would be less. The control flows at the East Branch Tully River intake are as follows:

TABLE 6

EAST BRANCH TULLY RIVER CONTROL FLOW AT INTAKE

	Jan Feb Mar	Apr May Jun	Jul	Aug	Sep Oct Nov	Dec
CSM	0.5	1.25	2.0	1.0	0.75	0.5
CFS	25	63	100	50	38	25

If the Connecticut River is above 17,000 cfs and the East Branch Tully flow is above the control flow for that given day, then diversion from the East Branch Tully River would occur. The rate of diversion on any given day could vary from near zero to 490 cfs, the maximum capacity of the tunnel.

The flow rates in the Connecticut, Millers and East Branch Tully Rivers would be automatically fed into the control centers at the Tully and

Millers River intakes. Also, water quality readings would be read from the monitoring station upstream of the Millers River diversion site and samples in the Tully River. This information would then be used to determine if the diversions would occur and if so, at what rates. Diversions might occur at both sites simultaneously or possibly only at one site depending on the river flows and water quality. The bascule gates and inlet gates at each diversion site would be regulated in such a manner as to divert the maximum total amount of water to Quabbin Reservoir. The entire operation would essentially be controlled from the Millers River intake.

The total project cost, including advanced waste treatment facilities, is estimated to be 41 million dollars based on May 1972 price levels. All costs include an allowance for contingencies, engineering and design, and supervision and administration. The estimated costs are based on knowledge of the site and experience on similar projects. Evaluations of property are based on real estate studies and information from local officials reflecting values in recent sales in the area. Average annual costs are based on an interest rate of 5-1/2 percent. The project is amortized over a 50 year economic life. Allowances for maintenance, operation and replacement of equipment have been included in the annual charges.

Multi-purpose applications of this project were also investigated. The Millers River would be returned to its previous excellent quality offering numerous recreation opportunities. Additional incidental flood control benefits would occur because higher discharges from Tully Dam would be possible, knowing that a maximum of 490 cfs would be diverted to Quabbin Reservoir. However, this would reduce the amount of water diverted from the Millers River because the maximum capacity of the 10-foot section of tunnel is 730 cfs. During times of potential flooding, coordination would be maintained between Tully and Birch Hill Dams and the two diversion sites to insure the proper operation for flood control. Still, the economic benefits for flood control protection attributable to this alternative are minimal, primarily because of the flood protection given by the existing dams.

The existing "Master Plan for Reservoir Development" of Tully Dam could remain essentially the same. Present considerations are for the development of a canoe and hiking reserve and a primitive camping area. Sanitary facilities would be designed to meet Massachusetts Department of Public Health Standards for water supply streams. Also, no diversions from Tully would occur during the recreation season. This would insure the protection of Quabbin Reservoir.

The present available data on the water quality and the quality of the bottom deposits are incomplete from a design viewpoint. Further sampling will be required to design the treatment systems and to determine resultant water quality after treatment of point sources. But after the plants are in operation and the river has stabilized, a permanent monitoring station would be required upstream of the Millers River diversion site. Measurements would be taken on a number of water quality parameters to insure that the water to be diverted is acceptable.

On the East Branch Tully River, no further water quality testing on a scheduled basis would be required. Samples would be taken on an intermittent basis (four or five times during the diversion period). If anything showed up in these samples, then a sanitary survey would be performed to isolate the problem.

The water quality of Quabbin Reservoir is also of major importance. So sampling station would be set up within the Middle Branch of Quabbin Reservoir. Similar tests would be run on these samples, as on the Millers River samples. If discharges are also made into the West Branch of Quabbin Reservoir, then other sampling stations would be set up.

2. Environmental Setting Without the Project

General Geology

Glaciation has modified the topography of the region by smoothing the hills and ridges, steepening some slopes and filling the valley bottoms. It is a region of long, broad ridges and rolling hills which rise in fairly steep but generally smooth and regular slopes above the relatively wide valleys. Till forms a generally thin mantle over the bedrock on the hills and occurs as thick filling in the valley bottoms under extensive outwash deposits which form wide, flat flood plains and prominent terraces on the valley walls. Locally, the valleys are constricted by rough and irregular kame deposits consisting of outwash and modified till. The bedrock of the region consists of a series of closely folded Carboniferous rocks, mainly schist and gneiss with large areas of granite and pegmatite. The folds trend generally north - south.

Geology of the Connecticut River at the Confluence of the Millers River

The following account is based on The Flow of Time in the Connecticut Valley: Geological Imprints, by George W. Bain and Howard A. Meyerhoff, The Connecticut Valley Historical Museum, Springfield, Massachusetts, 1963:

The drainage system of the older Connecticut Valley was buried in glacial times by the deposits of Lake Hadley. The river's present course was established on these lake sediments and the inner valley is excavated in them. Prior to post-glacial entrenchment, the southerly flowing reach of the river above the Millers River confluence was deflected westward across the lake plain by the delta of the Millers River. It turned southward again where it met the traprock ridge below the present location of Turners Falls. The Turners Falls Dam now marks the spot where the Connecticut River poured over the banks of the glacial lake and into the channel of its pre-glacial tributary, Falls River. The deep gash in the Triassic rocks here was formed by the falls receding upstream during the post-glacial age.

Above the confluence of the Millers River, the Connecticut River occupies a narrow rock gorge for about a mile northward, above which point the valley widens out. This section of the river's course as far north as Northfield was formed in the bed of glacial Lake Hadley. After washing away the loose deposits of the lake bed, the river

channel encountered a weak contact zone between Triassic conglomerates on the west bank and the metamorphic rocks of the higher ground to the east. The river deepened the channel in the contact zone thereby creating the scenic stretches now dominated by French King Bridge.

The composition of the river bottom in Massachusetts varies from rock, rubble, gravel and sand to mud, silt and clay. The majority of the exposed areas during low water stages are sand or gravel deposits.

Connecticut River Basin

The Connecticut River from its origin flows south for approximately 404 miles, the lower 60 of which are tidal, and drains an area of 11,265 square miles before emptying into Long Island Sound. The river flows through wilderness areas as well as highly populated urban communities such as Holyoke and Springfield, Massachusetts, and Hartford, Connecticut. Sixteen dams have been erected along the mainstem of the river, primarily to provide hydroelectric power.

The river supports industry, navigation, recreation, sport and commercial fisheries, as well as provides a domestic water supply to a number of communities in and outside the basin.

Historically, the Connecticut River has supported major runs of anadromous fishes including American shad, alewives, blueback herring, rainbow smelt, sturgeon, and Atlantic salmon. Though the first four of these species still complete their annual migrations for spawning within the lower reach, all were eliminated from the upper portion subsequent to dam construction. The Atlantic salmon has been entirely eliminated. A sport fishery does exist throughout the river's length; however, it reaches peak importance along the tributaries, largely through annual stockings of trout to maintain a "put-and-take" sport fishery. Efforts are being expended to restore anadromous fish to the entire watershed through construction of fish passage facilities at obstructions not having these and operation of salmon hatcheries. Pollution abatement programs to comply with State standards should lead to restoration of high quality aquatic resources and their utilization. The Environmental Protection Agency's pollution abatement schedule for the Connecticut River sets 1976 as completion date for pollution control facilities.

The proposed diversion site at Northfield Mountain is located with a soon to be completed pumped storage hydroelectric facility. The pumps would be used during the non-generating period for the transfer of water from the Connecticut River via tunnel to Quabbin Reservoir during the spring run-off period. Anadromous fish species are not now found in this portion of the river; however, 23 resident species have been collected within this reach according to the list on the following page.

FISHES COLLECTED IN THE CONNECTICUT RIVER, TURNERS FALLS TO VERNON DAM, 1970-1971.

American eel	Anguilla rostrata
Brook trout	Salvelinus fontinalis
Brown trout	Salmo trutta
Chain pickerel	Esox niger
Carp	Cyprinus carpio
Fallfish	Semotilus corporalis
Golden shiner	Notemigonus crysoleucas
Common shiner	Notropis cornutus
Spottail shiner	Notropis hudsonius
White sucker	Catostomus commersoni
Brown bullhead	Ictalurus nebulosus
Yellow bullhead	Ictalurus natalis
Banded killifish	Fundulus diaphanus
White perch	Morone americana
Largemouth bass	Micropterus salmoides
Smallmouth bass	Micropterus dolomieui
Pumpkinseed	Lepomis gibbosus
Bluegill	Lepomis macrochirus
Black crappie	Pomoxis nigromacultatus
Rock bass	Ambloplites rupestris
Yellow perch	Perca flavescens
Walleye	Stizostedion vitreum vitreum
Tesselated darter	Etheostoma olmstedi

Existing water quality is good to poor (B through D) depending upon location to population centers. The river receives both treated and untreated sewage as well as significant amounts of industrial waste.

Quabbin Reservoir

Quabbin Reservoir is the largest body of water in Massachusetts and the largest man-made impoundment in New England. It encompasses approximately 25,000 surface acres when full. Quabbin serves primarily as a domestic water supply source for 42 communities within the Metropolitan District Commission's jurisdiction. Public use of the impoundment is regulated by the MDC through controlled access and specific regulations. Quabbin has developed an excellent and popular sport fishery through the joint efforts of the MDC and the Massachusetts Division of Fisheries and Game. The more important species entering the sport fishery include: landlocked salmon, lake trout, small and large mouth bass, rock bass, pickerel, bluegill, pumpkinseed, brown bullhead, white and yellow perch, brown trout and rainbow trout. Some brook trout are taken in the tributaries.

Unpopulated State owned lands encompass more than 80,000 acres, most of which is covered by a dense coniferous forest. Although the project area contains an abundance of game animals, hunting is not allowed. Recreational use consists of regulated boating, fishing, sightseeing and hiking.

Millers River Basin

The Millers River rises in Ashburnham, Massachusetts, and flows in a westerly direction for about 45 miles through Winchendon, Athol, and Orange to its confluence with the Connecticut River at Montague and Erving, Massachusetts. It has a drainage area of 392 square miles.

Principal tributaries of the Millers River are the Otter and Tully Rivers. There are two completed flood control dams in the Millers River Basin: Birch Hill Dam on the Millers River, and Tully Dam on the East Branch of the Tully River. The Millers River Basin is characterized by 78% forest cover, 11% open land, 8% wetland, and 3% urban area.

The main stem of the river contains both treated and untreated domestic sewerage and substantial amounts of industrial waste from several communities. The Otter River, one of the main tributaries to the

Millers, is also heavily contaminated with sewerage and industrial waste, but for the most part, the small tributaries within the Millers River Basin are relatively free of pollution.

Good trout habitat exists upstream of the confluence with the Otter River within the Birch Hill and Winchendon areas, and this reach is stocked annually with rainbow trout by Massachusetts Division of Fish and Game. As a result of pollution in the Otter River and downstream reaches of the Millers River, a sport fishery is non-existent. Fish species consist primarily of suckers and bullhead. An occasional large mouth bass is taken well downstream near the confluence with the Connecticut River; however, the existence of this species is entirely dependent on water quality. White-water canoeing is a very popular recreational activity during the spring freshet season.

From the city of Athol extending downstream to the Orange dam, the setting is a wide level valley with the river meandering through an agricultural setting of pastures, meadows, and settled land. The stream bottom is mud and silt with extensive emergent vegetation as is the outlet of Lake Rohunta which joins the Millers River below Athol. The River is backed up by the Orange dam about a mile upstream. The zone between Orange and the Connecticut River is typified by steep banks, a sharp river gradient, long rapids followed by short pools, a complete absence of wetlands, and a boulder strewn rock rubble bottom. Some 22 species of fish are reported for the Millers River watershed. Population magnitude and locations are dependent on the particular species requirements as well as the man-made stress of pollution.

Tarbell Brook

Tarbell Brook is a small, low gradient stream approximately 7-1/2 miles long from its headwaters to its confluence with the Millers River. Open water areas (which include lakes and ponds) along the stream cover 1-1/2 miles. The total drainage area is approximately 27 square miles of which about five are wetland, less than two are open water, and the remaining area representing upland habitat.

Flow is moderately rapid through forested areas and slow in open wetland areas. Stream width varies up to 30 feet. Depth is variable and measures several feet in some places. Water quality is good (Class B). The adjacent habitat is primarily coniferous forest combined with mixed stands of hardwoods.

The stream is stocked annually with trout by the Massachusetts Division of Fisheries and Game which provide a "put-and-take" sport fishery. Several species of game such as woodcock, grouse, black duck, rabbit, squirrel, and deer inhabit the area.

During high water, Tarbell Brook is canoeable from the New Hampshire border to its confluence with the Millers River.

Priest Brook

Priest Brook, including Scott Brook, (its main northern tributary) extends approximately 14 miles from its headwaters in southern New Hampshire to its confluence with the Millers River. Open water areas cover one mile along the stream which is of moderate to low gradient and flows through forested and wetland areas. Width varies up to 40 feet and depth is variable, generally three feet but as much as six feet in some areas.

The total drainage area is approximately 23 square miles of which about three are wetland, less than one is open water, and the remaining area is upland habitat. Water quality is good (Class B) but below average for trout during summer months due to high temperature and low flow conditions. Adjacent habitat consists of coniferous forest with mixed stands of hardwood.

This stream is stocked annually with trout by the Massachusetts Division of Fisheries and Game which provides a "put-and-take" sport fishery. Waterfowl and other game species are essentially similar in types and number to that found in the Tarbell Brook watershed.

The proposed diversion site would be located approximately four miles due east of the town of Royalston in an unpopulated area, three miles above the confluence with the Millers River. The project area will encompass about 400 acres, including approximately 330 acres of wetland and 70 acres of upland habitat.

The following private developments are located within the project area. An extensive private camping development consisting of approximately 50 trailers and attendent facilities and a gun club facility including a clubhouse, target range, and a one-half acre pond, just north of Winchendon Road.

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Tully Reservoir

The East Branch Tully River extends about 15 miles from its headwaters in southern New Hampshire to its confluence with the West Branch Tully River. Open waters along the stream, including Tully Reservoir, cover six miles. The total drainage area of this river is 56 square miles of which about eight are wetland, six are open water, and the rest upland habitat.

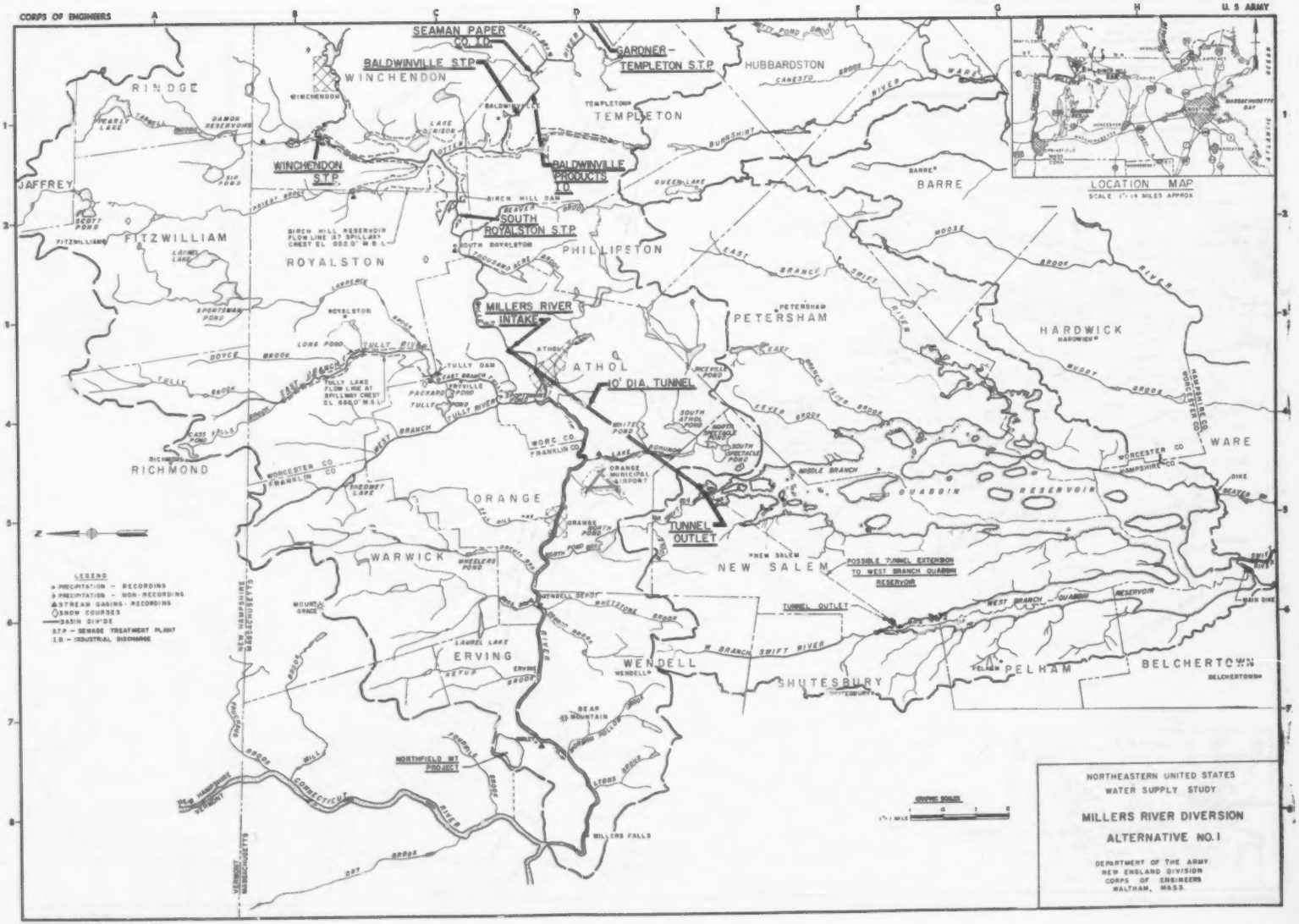
The river is of medium gradient with a section of slow moving water in the Long Pond area. Width varies up to 30 feet and depth up to 8 feet in some areas. Water quality is good (Class B) and is classified as "good trout water" on a seasonal basis. Terrain surrounding the river is moderately steep and heavily forested with mixed deciduous and coniferous trees.

The East Branch of the Tully River is stocked annually with trout by the Massachusetts Division of Fisheries and Game which provides a "put-and-take" sport fishery. Waterfowl and other game species are typical of those found in the Tarbell and Priest Brook watersheds. Considerable hunting activity for birds, small animals, and deer takes place in the basin. Numerous wood roads and trails remaining from past logging operations provide good access for hunters and fishermen. Recreation development potential is excellent and good white-water canoeing occurs below Tully Dam during periods of high water.

West Branch Tully River

The West Branch of the Tully River, including Tully Brook north of Sheomet Lake, is about 8 miles long, extending from its headwaters in central northern Massachusetts to its confluence with the East Branch of the Tully River, 1-1/2 miles north of Athol. The West Branch is of a moderate gradient, and is up to 35 feet wide with depths up to 5 feet along its course. Open water areas, mainly Sheomet Lake, cover only 1/2 mile along the river. Water quality is good (Class B) and the river is annually stocked with trout by the Massachusetts Division of Fisheries and Game. Total drainage area of the basin is about 19 square miles of which approximately 2 acres are wetland and the remainder upland.

The river flows through a relatively unpopulated and heavily wooded (mostly of mixed coniferous and hardwoods) area. Wildlife found in this basin is similar to that of the nearby East Branch Tully, Priest and Tarbell Brook areas.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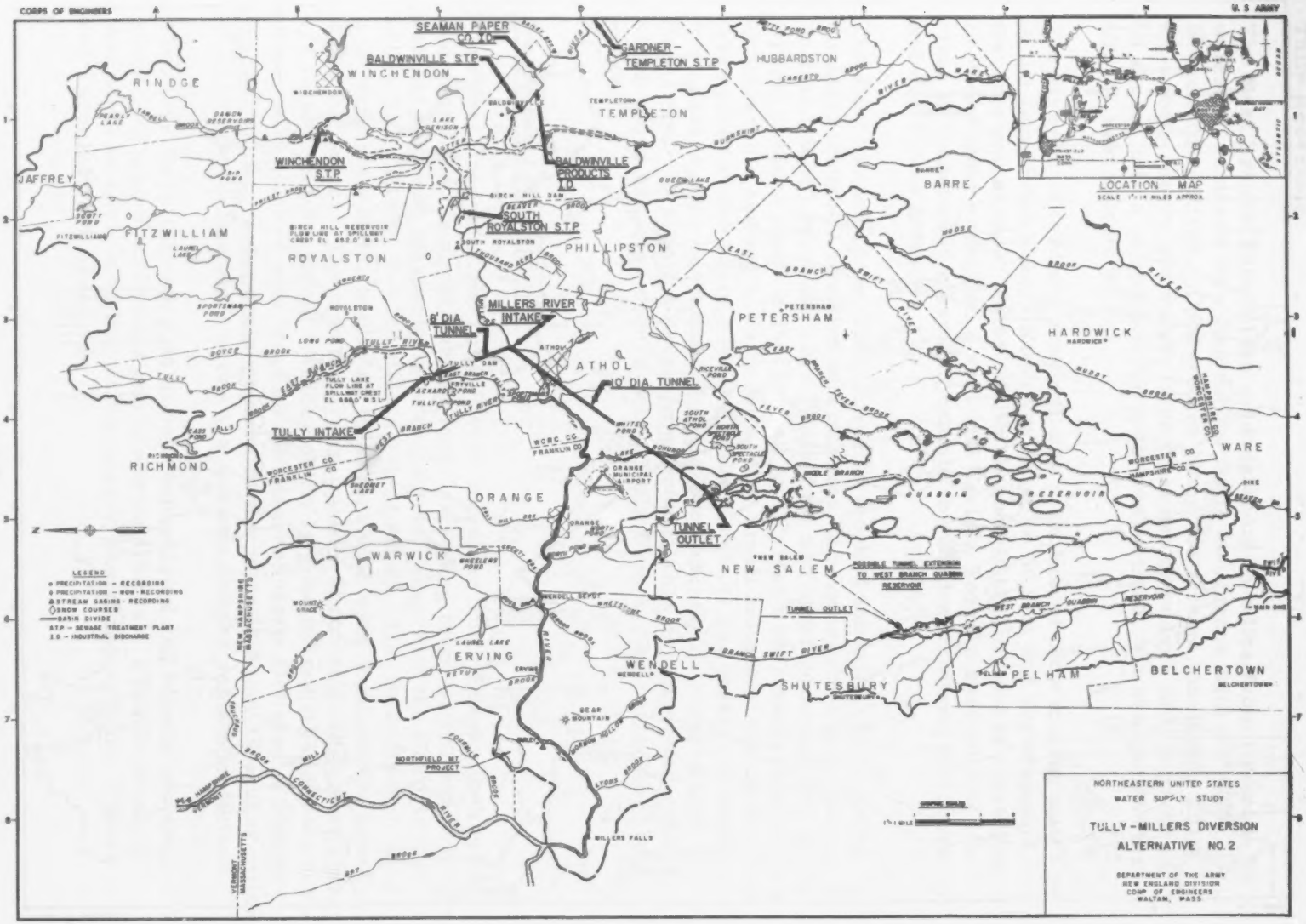
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LEGEND
P PRECIPITATION - RECORDING
p PRECIPITATION - NON-RECORDING
S STREAM GAGING - RECORDING
SNOW COURSES
BASIN DIVIDE
S.T.P. - SEWAGE TREATMENT PLANT
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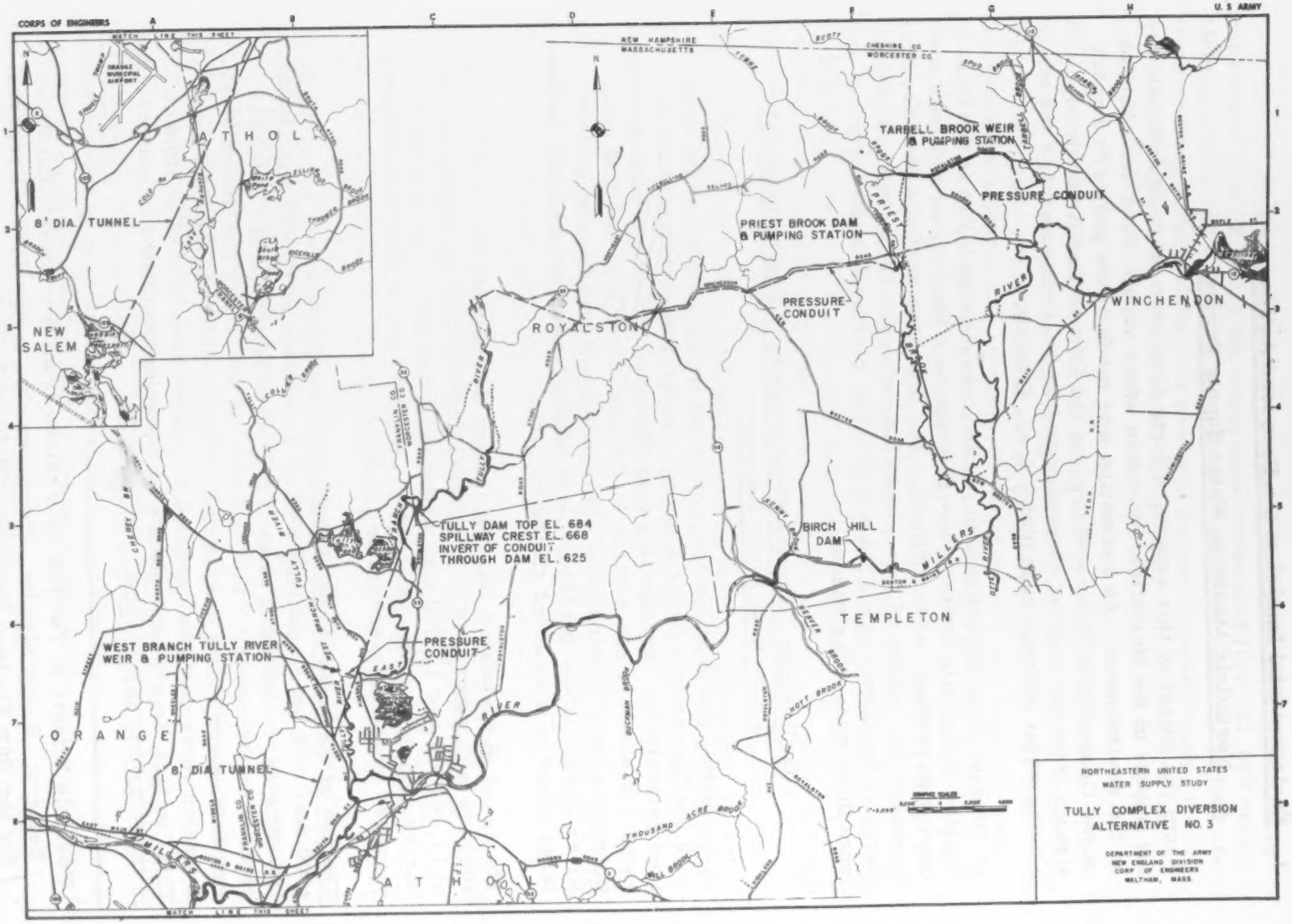
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3. Environmental Impact of the Proposed Action

A. Northfield Mountain Water Supply Project

From the outset of this report, efforts have been made to determine the impact of the Northfield Mountain water supply diversion element on the environment. An evaluation was made of the project's impact on the Connecticut River estuary, on the Connecticut River downstream from the point of diversion and on the environment of the receiving water storage reservoir, i.e., Quabbin.

To conduct these investigations, both in-house capability of the New England Division's Environmental Resources Section, as well as contractor personnel, were utilized. The following sections describe in summary the efforts of this integrated multi-discipline team of both Corps of Engineers and Fish and Wildlife personnel and services from three consulting firms.

1) Possible Environmental Impacts of Diversion on the Connecticut River Estuary

In evaluating the possible environmental impacts which might occur with the Connecticut River Estuary, contractor services were utilized extensively. Recognizing that this project's proposed diversion rates are small in comparison to the total river flow and that other proposals for diversion were also being considered in the Millers River Basin, it was decided to test effects[1] which might occur with a large range of postulated diversion rates.

The range of postulated diversion rates tested varied from 600 cfs to 4000 cfs with adherence to a minimum control flow at Montague City of 17,000 cfs and 12,000 cfs, as measured at the U. S. Geological Survey gaging station. Only the 17,000 cfs control flow rate has been approved by the Massachusetts Legislature.

The use of the large range of postulated diversion rates, i.e., 600 to 4000 cfs, with corresponding control flow rates of 17,000 and 12,000 cfs, thus were adopted to allow a full investigation of any potential impacts on the estuary. For example, if the larger postulated diversion rates were tested and limited impact predicted, then the lower diversion rates could be expected to exhibit even less of an impact. This, in fact, is what the results of the study concluded as summarized in the following paragraphs.

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[1] Possible Effects of Various Diversions from the Connecticut River Estuary. Essex Marine Laboratory, Inc., May 1972. Prepared for the New England Division, Corps of Engineers.

a) Changes in river temperature due to diversion should not exceed 0.61° F under the worst case postulated (i.e. 12,000 cfs at Montague City and 4,000 cfs diversion). Although many biological effects of temperature elevations are well known, in most cases, the effects resulting from such a small temperature increment are too small to quantify.

Biological evaluations were made using a 2° F temperature rise in the estuary. The rationale for choosing this temperature rise is twofold. First, biological changes could not be predicted on much less than a 2°F increment of change; and secondly, it would be only an academic exercise to try to refine predictions at a smaller increment of change if, in fact, no significant changes would occur at the 2° F increment. As it turns out, even a 2° F temperature rise would not cause a serious impediment to diversion plans as far as the ecological balance of the estuary is concerned. Keeping in mind that the calculated temperature rise is less than 1/3 the value used in biological evaluation (.61° vs. 2° F), the reader is advised of the apparent conservative nature of the biological evaluation that is summarized in the following paragraphs.

Among the known biological effects of increased temperature, the following may be expected, but it should be kept in mind that even if deleterious, the small change in temperature will result in too small a magnitude of change to be cause for alarm.

All of the conclusions regarding temperature and biological change are based on the worst condition tested, i.e., 4000 cfs diversion with 12,000 cfs at Montague City.

(1) Change in The Time and Location of Shad Spawning - Calculations indicate that a 2° F temperature rise in the river water would have caused spawning to occur 3.4 days earlier in 1967 and 3.6 days earlier in 1968. It is postulated that the most severe postulated diversion conditions would have an insignificant effect on shad spawning.

(2) Shad Egg Size, Abundance, Development Time and Mortality - Shad spawning success in general will not be greatly influenced by any of the postulated diversion. After diversion, temperatures would still remain well within normally occurring variations; and since spawning occurs well above salinity intrusion, any changes in salinity patterns will not affect spawning.

(3) Effects of Survival of Larvae of Shad and Resident Fish Species - Temperature rise and salinity changes that would be brought about by postulated diversion are not expected to affect the egg or larval survival development or growth of any of the fish species tested.

(4) Adult Fish Populations - Some adult fish could feel an effect of the diversion as a result of shifting (in time) of the availability of

a food supply. Food generally becomes available as temperatures exceed 40° F. A 2° F temperature rise would have caused this 40° F temperature to be reached 4.3 and 6.8 days earlier in 1969 and 1970, respectively. Since some adult fish winter in coves and do not move out into the river until temperatures reach 40° F in the coves, they may arrive in the river up to a week after the food supply begins to develop. This assumes that water temperature in the coves would not be influenced by the 2° F temperature rise in the river. More information is needed in this area to draw any definite conclusions, but no problem of significant proportions is anticipated.

(5) Homing Ability and Timing of Arrival of Adult Shad - Adult shad appear to have no homing problems even during extreme low flow springs. Diversion will not reduce flows during these extreme low flow conditions so that it is logical to assume that the shad's homing will not be impaired by diversion. Historically, it has been found that shad tend to enter the estuary when temperatures reach 40° to 43° F. Diversion would cause these temperatures to be reached somewhat earlier, but no problem is anticipated.

(6) Microbiological Population - Because of the paucity of data in some critical areas of basic biology, deemed pertinent considering the postulated diversion, no absolute predictions can be made regarding the ultimate fate of microorganisms in the estuary. Since temperature and salinity rise are so small (2° F and a few mg/l) at any given point and since these changes develop over a period of time, no significant qualitative or quantitative alterations of bacterial populations are to be expected in the short run (a few years). Beyond this span any prediction would be speculative.

(7) Invertebrates - 48 recurring species of invertebrates have been identified in 60 months of sampling. Of these, four species are dominant. A 2° F temperature increase can be expected to increase the metabolic activity and probably advance sexual maturity slightly in each of the above species. However, since considered diversions will not be made during summer low flow, high temperature situations, these species are not put under any undue stress. Temperatures after diversion will still be well within the limits of naturally occurring variation, and only minimal adverse effects are to be expected.

b) Freshet conditions should continue throughout the estuary if no diversion takes place when flows are less than 17,000 cfs at Montague City. The duration of freshet will be shortened by 2 to 4 days at both the onset and cessation of freshet in a normal year with diversion. If 12,000 cfs were considered as a control flow, then freshet conditions would be shortened by 3 to 9 days at both the onset and cessation of freshet in a normal year.

c) At a 12,000 cfs controlling flow at Montague City, minor reversals of current may occur in the lower estuary. These should not be sufficient to cause a biologically significant intrusion of salt water from Long Island Sound.

d) Under either controlling flow regime, changes in salinity distribution would be too small to have measurable biological effects.

2) Possible Environmental Impacts of Diversion on the Connecticut River

a) Impact on Aquatic Life

Diversion at Northfield Mountain may affect the aquatic life in the Connecticut River at the diversion point. Fishes, phytoplankton and invertebrate organisms of all life stages, may be entrained and/or entrapped at the pumping facility, whether diversion takes place or not.

The fish population, while composed of many species, contains only a few which are at the top of the food chain. These are: pike perch (walleye pike), small and large mouth bass and yellow perch. Studies by the Massachusetts Division of Fisheries and Game indicate that this reach of the river is underfished and the walleye population is probably almost completely composed of young fish descending the river from above Vernon, Vermont. The probability of great numbers of fish being transported into the pumps appears quite remote. This conclusion is based on several facts. One, only in a very limited part of the intake canal would the current be moving faster than in the main stream, thus older fish would not be carried into the canal against their will. Secondly, bass and catfish have specialized requirements as to where they build their nests, one of which is to locate outside of areas of strong currents. By the time the young leave the vicinity of their nest, they would be old and strong enough to avoid the canal. Further information on the biota and sport fish are provided in General Responses in Section 8. It is quite probable that the eggs and young of minnows and suckers will be carried through the pumping cycle and will have a high percentage of survival. Until such time that a fishway is constructed to pass anadromous fish over the Turners Falls Dam, sea-run fish will not be able to reach the intake canal.

As described earlier, the diversion for water supply purposes would withdraw about 580 cfs from the river, and this flow would then be

conveyed to Quabbin Reservoir. Diversions would only be made contingent on a minimum control flow of 17,000 cfs as measured at the U. S. Geological Survey gaging station at Montague.

Based on long-term stream flow records maintained at the Montague City gage, the amount of water to be withdrawn would be about 1% of the average annual run-off from the river. In addition, the maximum decrease in river stage caused by the diversion would be about 0.2 feet at Montague City or about .05 feet at the Thompsonville, Connecticut gage, while average river stage at Montague City at 17,000 cfs is about 12.75 feet.

b) Change in Concentrations of Nutrients

Based on data developed by the University of Massachusetts as part of a research grant, ammonia-nitrogen loads in the Connecticut River at Northfield for 1963 - 1965 were 3,800 pounds per day. Downstream at Thompsonville, Connecticut, loads for the same period were recorded as 35,900 pounds per day. Phosphate-phosphorous at Northfield for 1963 - 1965 was estimated to be 6,700 pounds per day, while at Thompsonville, about 33,000 pounds per day were recorded.

The diversion from the Northfield Mountain would little affect nutrient levels downstream from the diversion. Maximum differences in concentration at Thompsonville for ammonia-nitrogen and phosphate-phosphorous would be less than .01 ppm.

Since pollution abatement schedules call for installation of waste treatment facilities by 1976, the actual effect of diversion would be even less.

c) Change in Coliform Levels

Work conducted at the University of Massachusetts on this subject had among its conclusions, "A diversion of Connecticut River water at Northfield would reduce the flow and increase the coliform concentration. This seems reasonable since relatively coliform-free dilution water would be diverted. However, a reduction in flow at Northfield caused by the proposed rate of diversion would probably have no significant effect on coliform concentration at Enfield."

d) Effect on Downstream Wetlands

As stated earlier, the diversion at Northfield would lower river stages at Montague City 0.2 feet at a maximum. Downstream at Thompsonville, the stage reduction would be .05 feet. Minimal impacts to downstream wetlands are foreseen for these limited river stage reductions.

e) Effect on Planned Water Quality Improvements

Implementation schedules for waste treatment facilities on point sources of pollution have been established by the Environmental Protection Agency and the basin states. All plans for pollution abatement are based on meeting adopted water quality standards during low flow conditions. Since diversions considered in this project would only occur during high flow periods when flow is 17,000 cfs or greater at Montague City, no impact would occur to impair planned water quality goals.

f) Effect on Water Temperature

Studies conducted within the estuarine portion of the basin indicated a maximum of 0.06° F rise could be expected in the estuary following diversion of 600 cfs. Upstream in the mainstem of the Connecticut River, the maximum change in temperature which would be caused by the diversion and subsequent loss of dilution flow would be about 3%. No significant effect on water temperature is anticipated, therefore, from the diversion.

g) Change in Level of Groundwater Table

Discussions were held with the U. S. Geological Survey to determine the impact which the diversion may have on groundwater levels. In the opinion of the Geological Survey, no significant impact to groundwater levels is anticipated as a result of the diversion -- letter, 7 April 1972.

h) Effect of Diversion in Flood Flow Bottom Deposit Scouring

Based on studies [1] by the University of Massachusetts, it was estimated sediment load transport efficiency of the Connecticut River just downstream from the diversion intake would be reduced approximately 3 percent. Downstream from the intake, flow from intervening drainage area would cause the reduction in efficiency to be even less.

i) Effect on Aquatic Life in Vicinity of Diversion Intake

Diversion of water from the Connecticut River to the Northfield Mountain upper reservoir may affect the aquatic life in the vicinity of the river intake. Fishes, phytoplankton and invertebrate organisms of all life stages may be entrained and/or trapped at the pumping facility.

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[1] Appendix C, "Report on formation of public policy on issue of out-of-basin diversion of Connecticut River flood waters to Boston metropolitan area" Water Resources Research Center, University of Massachusetts, Amherst, Massachusetts.

This impact is not occasioned by the fact of the water supply diversion, but rather by the operation of the Northfield Project for power production.

j) Effect on Downstream Navigation

Below Hartford, Connecticut, the river is used for both commercial shipping and recreational boating. Upstream from Hartford to Holyoke, the river is used for recreational boating, but sand bars and shallow water during low flow greatly impede navigational use.

Normal navigation season flow at Hartford is considered to be 3,750 cfs, while the upper limit is considered to be 66,000 cfs.

The diversion would not affect low flow navigation conditions. High flow conditions would be affected, but not in a negative manner. Instead, the reduction in flow from the diversion would be a minor benefit due to slightly lower velocities.

k) Effect on Flood Control

The Corps of Engineers is presently working with electric utility officials on an operational schedule of the Northfield Mountain project during flood periods. At present, a draft report presenting methods of operation is under review. It is anticipated that operation of the facility would not have a detrimental effect on flood control measures within the basin.

3) Possible Environmental Impacts of Diversion on Quabbin Reservoir

This study [1] generated and evaluated extensive data on the Quabbin and Wachusett Reservoirs and the Connecticut and Millers Rivers systems, with the objective of making predictions on the impacts of diverting portions of these riverine systems into Quabbin Reservoir. Field and laboratory data included approximately 100 parameters, including chemical, physical, biological, and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information, and pollution abatement plans were considered and evaluated. Finally, other pertinent data available from both public and private sources, especially on the Connecticut River, were evaluated in the light of the objectives of this study. A summary of this evaluation is given in the following sections.

[1] Water Quality Studies, Connecticut and Millers Rivers Systems and Quabbin and Wachusett Reservoirs, New England Research, Inc., June 1972, Prepared for Metropolitan District Commission and Army Corps of Engineers.

Central to the evaluation was the development of a qualitative model of reservoir dynamics. If water of lower quality is introduced from a river system into a receiver system, there will most likely be a loss in water quality in the receiver system. This loss of water quality is due to various materials in the water. These materials include molecules, ions, suspended inorganic materials, organic debris, and living organisms. One of the central problems of ecology today is to trace the flow of materials from the various compartments of an eco-system.

a) Possible Impact on Water Quality

In this section, changes in water quality as a result of the proposed diversion are evaluated. The discussion is limited to the more important issues; no attempt is made to discuss all parameters. Subsequent sections will deal with broader ecological issues, and will include most of the biological parameters.

Diversion of Connecticut River water into Quabbin Reservoir in 1976 will initially increase the turbidity of the reservoir water. The final turbidity will depend upon (1) fallout of some material, (2) the relative dilution of Connecticut River water by ambient Quabbin volume, (3) transformations of materials, (4) the influence of ionic strength changes, and the influence of pH changes. Based on only preliminary data, the fallout of material could be significant after a residence time of 60 - 90 days. The dilution, however, can never exceed a factor of about 5 to 10, depending upon what volumes and how much mixing one considers. Also, water originating in the Connecticut River will be between 18 and 19% of the volume of the entire reservoir, depending on the availability of other diversions during the period 1980 to about 2000. Transformations may change the molecules or colloidal aggregates, but will not necessarily cause an elimination. Finally, the Connecticut River water will undergo a drop in specific conductance after it enters Quabbin; this will tend to stabilize the colloidal suspensions. If it is assumed that the Connecticut River will have an average turbidity of less than 25 during freshet flow, and that extremely high values are possible but infrequent occurrences, all factors considered above will tend to bring the final turbidity down to a lower value. While it cannot be predicted what this value will be, it will probably vary between 0.5 (present turbidity) and about 2. Thus, it may not meet future U. S. Public Health Service (1 JTU) standards for drinking water. The turbidity will probably not rise as much during the first two diversion cycles (years 1976 - 1978) because of the smaller relative proportion of total water originating in the Connecticut River.

Ions that form insoluble complexes (Mn, Fe, Ca) tend to precipitate out into the sediment if suitable anions are available. Such anions decrease

as the pH becomes more acid, and thus these ions will tend not to precipitate out as the Connecticut River waters mix with Quabbin waters. Depending on the quality of other waters introduced to the reservoir in the future, there may be a tendency to balance. However, it cannot be predicted what the trend will be over a two-decade period, because the exact proportions cannot be predicted and the long-range stability for pH values in all systems is unknown.

There are at least two major concerns on the possible deterioration of water quality that have ecological significance. One concerns oxygen depletion, and the other is the introduction of additional nutrients which can lead to eutrophication.

Available data suggests that Chemical Oxygen Demand (COD) values for the Connecticut River are about twice as high as the Quabbin stations. Both Connecticut River and Quabbin Reservoir waters maintain high 0_2 levels, and during the freshet flow periods are probably close to saturation. The concern here is an assessment of the potential depletion of 0_2 from Quabbin waters as a result of the proposed diversion.

COD represents a potential 0_2 consumption that is measured using a strong chemical oxidizing agent. Depending on the ease with which the material can be oxidized under natural conditions, the full COD may or may not be exerted upon the water.

If most of the COD is in particulate form (which is probably true for the Connecticut River) much of the material with a potential demand for oxygen could settle out either in the Northfield Pumped Storage Reservoir or in upper Quabbin Reservoir after diversion. Although settling reduces the COD of the water column, the potential oxygen demand is conserved in the mud. Moreover, the organic component of the sediment may be acted upon at the mud-water interface, and transformed into more easily oxidized compounds. Some materials in the diverted waters may interfere with biological activity in the mud-water interface and either inhibit or enhance the transformation processes. Seasonal turnover and wind effects can stir up these bottom deposits into the water column. These effects are intensified if the reservoir levels decrease. The resuspension of transformed organic muds can serve to deplete available oxygen quickly because COD that had accumulated over many years through the settling process is suddenly present in the water column. If the stirring of the bottom mud never occurs, then COD that is settled out may be buried in the anerobic sector of the mud and may never exert its 0_2 demand on the water.

Included in COD values are the oxygen demands of inorganic materials such as iron and manganese. These inorganic species can have high 0_2 demands if they are in a chemically reduced state. However, in the Connecticut River, laboratory analysis shows that the iron is mainly Fe III and that the manganese may also be already oxidized.

All the above factors make it difficult to predict the impact of diverting Connecticut River waters with a higher COD into Quabbin Reservoir. Localized oxygen-depletion effects have been observed in the eastern arm of the reservoir. It is probable that similar effects will be observed after diversion in the northern part of the reservoir as well. The impact on the hypolimnion in the deeper part of the reservoir cannot be predicted at this time. Oxygen depletion will depend on a complex of biological and chemical processes in these aquatic systems. In conclusion, then, it is very possible that the proposed diversions may result in some localized oxygen depletions in the reservoir. The extent and magnitudes of such depletions cannot be predicted. The impact on Quabbin must be carefully observed and monitored. If necessary, the option of diverting flow to more than one location within the reservoir can be exercised by extension of the tunnel stub to the the West Branch of the Reservoir.

A number of mechanisms can be expected to operate after the diversions of river waters. Much of the larger material will settle out, probably within hours and days. Many transformations can be expected, based on both inorganic and biological reactions. Detergents would be degraded, although no significant MBAS[1] levels were found. As the carbonates from the Connecticut River reach the more acid reservoir waters, equilibria will shift and some CO_2 will go off to the atmosphere. Organic materials including the CCE will probably be oxidized. Some NH_3 may also be oxidized, but most of it would be transformed by the biota. Color would decrease. This loss of color could be at least tenfold, based on evidence from the existing Ware River diversion. Finally, many highly insoluble organic materials, including hydrocarbon pesticides and organomercury compounds would tend to evaporate, as they reach the relatively large surface area of the reservoir.

The general trend will be towards an improvement in quality as the diverted water is retained in the reservoir. Whether the retention time within the reservoir before the Connecticut River water reaches the general position near the reservoir main water supply outlets is sufficient to cause recovery is unknown. However, the much longer

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[1] MBAS - Methylene blue active substances, found in most household detergents.

retention times to reach the Chicopee Valley water supply outlet could also allow for some recovery. It cannot be predicted that dilution with ambient reservoir volume will not restore the water quality alone. Some "fallout" of materials due to sedimentation, transformation and evaporation must occur to restore quality. The "treatment plant" capacity of the reservoir can probably handle some restoration of water quality. The magnitude of this capacity is now unknown. Because of its capacity to handle waters from the Ware River diversion with efficiency for 30 years of diversion, we may assume it has some reserve capacity. However, assuming that a loss of water quality occurs with some diversions of Connecticut River water, further deterioration will be checked if other sources of supply are added to the reservoir.

In summary, then, during the period prior to the Northfield Mountain diversion, the water quality will deteriorate as the volume in Quabbin Reservoir decreases. This loss of quality could progress to a dangerous point if the volume of hypolimnion waters is drastically reduced. Any losses in quality due to Connecticut River diversion must be judged in the light of water quality loss without diversion. Secondly, the volumes of water represented by Connecticut River origin will be relatively low during the first few diversions. This allows ample time to study the actual impact of diversion during a period of lower potential to cause a negative impact on water quality. Thirdly, future additions of water to Quabbin from other sources should improve the "treatment plant" capacity of the reservoir and thus an improvement in quality may take place. Also, it must be remembered that as the pollution abatement plans are implemented in the 1970's, the quality of riverine waters will improve. Finally, without even further sources of water inflow, Quabbin Reservoir is destined to deteriorate rapidly by the end of the century.

b) Possible Impact on Ecology

There can be little doubt that increased levels of nutrient chemicals will be detected in Quabbin Reservoir after the implementation of the Connecticut River diversion. However, not all nutrients can be expected to show such an increase in this time period. Phosphorus increases are possible, but not probable. Increases in available carbon, on the other hand, are quite probable if only due to the relatively high alkalinity of the Connecticut River. Also, the fact that fecal contamination of the Connecticut River does occur, increases the likelihood that complex organic molecules will be introduced into Quabbin and possibly into Wachusett where they will become part of the nutrient pool. The

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future abatement of pollution in the Connecticut River will contribute significantly to the lowering of any such nutrient addition to the reservoir through diversion.

It is important to note that current nitrogen, phosphorus, and carbon levels in Quabbin are sufficient to support larger phytoplanktonic populations than presently exist. Increased levels of these nutrients do not necessarily mean, then, that higher concentrations of algae in Quabbin can be expected as a direct result of the diversion. It is quite possible, however, since nitrogen, phosphorus and carbon appear not now to be limiting, that the Connecticut River diversion may increase the levels in Quabbin Reservoir of some now unknown limiting growth factor, such as a vitamin. Additional studies on limiting growth factors in both Quabbin Reservoir and Connecticut River water is now under way by the MDC.

There is no reason to believe that undesirable algal species will be introduced into Quabbin Reservoir by either diversion. Any changes in the current algal populations in Quabbin will most likely be the result of the response of present populations in Quabbin to changing levels and kinds of nutrients brought about by the diversions.

The proposed diversion of Connecticut River waters into Quabbin Reservoir presents a good possibility of having an impact upon the maintained fisheries of Quabbin. Furthermore, in view of the fisheries management objectives of the Massachusetts Division of Fisheries and Game, the impact would be a negative impact. If it is assumed that undesirable species will be introduced into Quabbin Reservoir, then the consequences could be felt in several ways. First, the present managed ecological balance between species will be lost. Secondly, if the salmonid population is decimated by undesirable species competition, and a warm water fish population predominates, there is good likelihood that the number of angler trips by sports fishermen to Quabbin Reservoir will decline. This, in turn, will reduce the harvest and further influence ecological balance. The issue, then, is not a reduction of the standing crop of total fishes in Quabbin Reservoir, but the disruption of the present success in the management of a salmonid fisheries program. Studies on methods of excluding undesirable species and hence the consequences associated with their introduction are now being discussed by the MDC and the Massachusetts Division of Fish and Game.

Increased concentrations of organic molecules in Quabbin as a result of the Connecticut River system diversion may affect the dissolved oxygen content of Quabbin waters due to the oxygen demand of these molecules as discussed earlier. The magnitude of any overall decrease

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in oxygen in the hypolimnion of Quabbin Reservoir, however, is not expected to cause significant changes in the present ecology of Quabbin Reservoir. Localized depletions of oxygen in Quabbin Reservoir have been periodically noted over the past half dozen years as a result of the present Ware River diversion. These depletions have been observed only in the southern part of the eastern arm of Quabbin, and have been short lived. The proposed diversions may be expected to produce similar, localized phenomena. The salmonid fisheries in Quabbin are not expected to be affected by any lowering of dissolved oxygen which is localized in the upper portion of the middle arm and in the eastern arm because they are typically found in the main body of Quabbin.

Because of the number of factors governing the disposition of pesticides in surface waters, it is not surprising that only small traces of pesticides were detected in this study. Similar findings are seen in the STORET retrieval data on the Connecticut River. Analyses for aldrin, BHC, DDT, dieldrin, endrin and other pesticides during the 1960's show little or no residues in the water. Finally, the findings of Lichtenberg et al. (1970) in a 5-year summary of pesticides in surface waters of the United States report only trace amounts (0.1 ppb) of pesticides in the Connecticut River.

A prediction with some certainty can be made about the ecological effects of pesticides in the proposed diversions. The Massachusetts Division of Fisheries and Game has data that indicate significant levels of DDT, endrin, dieldrin and PCBs in the tissues of lake trout taken from Quabbin Reservoir. These pesticides in lake trout reflect the expected concentrations by the food chain if traces of pesticides are already available in the reservoir ecosystem. Nor were the residues of DDT in fish from the Connecticut River (Lyman et al. , 1968) any higher than those reported for the fish in Quabbin Reservoir. While more extensive monitoring of the waters, muds, and biota of both the Connecticut River and Quabbin Reservoir for pesticides would increase the certainty of prediction, it is highly improbable that the proposed diversion will have any important environmental effects.

Similarly, the impacts of the proposed diversions into Quabbin or Wachusett Reservoirs are impossible to discuss in detail until such a time as the specific impacts discussed above can be more fully defined by future studies. On the basis of current data, the possibility of a degeneration in turbidity in Wachusett deserves some mention due to the importance of turbidity in any contemplated future treatment of Wachusett waters prior to their final distribution to consumers. Further studies sponsored by the MDC are presently under way on possible impacts in both Quabbin and Wachusett Reservoirs.

c) Public Health Aspects

Coliform bacteria are indicators of possible human fecal contamination and therefore of the possible presence of human pathogens, including bacteria and viruses. Coliform bacteria are not themselves, however, pathogenic. It is reasonable to assume that concentrations of coliforms will increase in Quabbin Reservoir as a direct result of the Connecticut River diversion. Therefore, the possibility of finding agents of human infection in the area of Shaft 12 in Quabbin will also be increased by the diversion. The measure of real risks to public health associated with this possibility is, however, a function of a number of other variables. These variables include the general health of populations contributing to the fecal pollution of the Connecticut River, treatment of water before its entry into Quabbin, residence time of this water in Quabbin, dilution of diverted waters by Quabbin waters; and finally, treatment prior to final distribution.

While the MDC is currently planning, according to a Massachusetts Department of Public Health directive, to chlorinate diverted waters prior to their entry into Quabbin, varying turbidities of these waters, and the resultant inefficiencies of chlorination, will ensure the possibility that pathogens imbedded within suspended debris could find their way into Quabbin. Chlorination of diverted waters prior to entry into Quabbin depending on turbidity will probably be less important a means of controlling the introduction of these pathogens than will the implementation of present pollution abatement plans for the Connecticut River.

Even with the implementation of present abatement plans, an important question is how long diverted waters can be expected to remain in Quabbin. In general, the natural purification processes of a lake will reduce the coliform concentrations in proportion to the length of time these bacteria are in residence in the lake. The die-off rates of coliform bacteria are generally considered to be similar to die-off rates of pathogens. While recent research indicates that there is not necessarily a direct correlation between the die-off rates of coliform bacteria and pathogens, it is generally assumed that resident times of several weeks provide reasonable disinfection (Fair, Geyer, and Okun, 1968).

Model studies thus far indicate that diverted waters will have reached the general area of Shaft 12 within 2 - 3 months of the time they are introduced into Quabbin. Portions of these waters will be mixed with waters derived from the southerly portions of the main body of the reservoir as they are taken into Shaft 12; other portions will continue

in a southward flow to mix eventually with the waters in the western arm. While it can be expected that significant die-offs of pathogens will occur within a 2 - 3 month residence in Quabbin, and that maximum dilutions of diverted waters will probably be realized within one diversion cycle, the possibility that some pathogens may find their way into the Quabbin aqueduct has to be assumed. The possibility that some pathogens will find their way into the Chicopee outlet at Winsor Dam also has to be assumed; however, because preliminary laboratory model studies indicate it will take about 7 months for diverted waters to reach Winsor Dam, and because of the greater dilution of these waters which would then have taken place, the probability of detecting pathogens at the Chicopee aqueduct would be lower than that of detecting them at the Quabbin - Wachusett aqueduct.

Because model studies to date have not taken into account the effect of winds on residence times of diverted waters, and because pertinent information of the die-away phenomenon is by no means complete, it is not now possible to predict the actual number of pathogenic organisms which may possibly find their way into the Quabbin - Wachusett and Chicopee aqueducts as a result of the Connecticut River diversion.

It is important to note that any pathogens which do find their way into the Quabbin - Wachusett aqueduct will be subjected to dilution by Wachusett waters as well as to the self-purification processes of that reservoir. Given the dilutions and residence times of diverted waters in both reservoirs, we conclude that while the introduction of pathogens into Wachusett Reservoir is possible, it is improbable that they will be detected in Wachusett. Finally, any enteric organisms which may be present in Wachusett as a direct result of the contemplated diversion may be easily destroyed by existing or contemplated chlorination within the distribution system.

The presence of mercury at all sampling sites suggests that it is reasonable to assume that mercury is a component of the waters of this region. While the levels are generally low and thus pose no immediate hazards, the possibility of significant concentrations in the food chain must be assumed. Indeed, data from the Massachusetts Division of Fisheries and Game indicate levels of mercury in fish taken from Quabbin Reservoir to be in the range of 10^2 - 10^3 ppb, in this regard being similar to levels found in fish in the Connecticut River. Several peak values for mercury in the water column in excess of 5 ppb have been found in some locations, including the Millers River and Quabbin and Wachusett Reservoirs[1]. Most of these values

[1] Note: all of the higher values recorded for reservoir water were recorded in the results of one sampling run. Samples collected in the months prior and following this run indicated lower values.

occurred earlier in the year, and recent data indicate lower values. The reasons for these values are unknown, nor can the present study, due to the sampling situation, define any possible sources. Our conclusions on the impacts of the proposed diversions, however, must be based on comparative data for the proposed donor and receiver systems. On the basis of the data, we must conclude that no public health hazards due to higher levels of mercury can be expected from the proposed diversions. Indeed, the data suggest that lower levels in water exist in the proposed donor systems.

Pesticide information was reviewed. The findings confirm the position that the Connecticut River waters would not present a public health hazard if diverted into Quabbin Reservoir. In the first place the amounts of pesticides are too low, and secondly the evidence indicates trace amounts to be present in Quabbin Reservoir already. Therefore, the proposed diversion would not introduce pesticides into a reservoir that was already free from such compounds before the diversion.

Our data on radioactivity leads us to conclude that no public health hazards will result from the diversions of Connecticut River waters into Quabbin Reservoir. The Lawrence Experiment Station has been testing Connecticut River water as part of the cooperative efforts of the Tri-State Commission for some time, and has detected neither ^{226}Ra nor ^{90}Sr in the water. Also surface waters, including reservoirs, from all over Massachusetts have been treated in the spring and fall, and no presence of ^{226}Ra or ^{90}Sr has been detected. On the other hand, some of the STORET Data (Retrieval Date 69/02/27) for 1960's show Connecticut River water with total beta activity in excess of 10 uuc/liter. This is not true for the more recent data. These discrepancies are common for Connecticut River data, and point out the need for continual monitoring. Such continual monitoring is also desirable in view of the future operation of a nuclear power plant at Vernon, Vermont. Studies support the conclusion that, in view of existing guidelines, we see no immediate or long-range public health hazards from radioactivity in the donor systems.

The risks to human health which are inherent in the consumption of any surface waters cannot, of course, be completely eradicated. However, given man's past experience with public water supplies and his present technology, we conclude that those risks which can be associated with the proposed diversion are reasonably comparable with those generally taken in the consumption of Massachusetts surface waters.

A summary of impacts on Quabbin Reservoir, which may be brought about by the proposed diversion via Northfield Mountain, is shown in Table 7.

TABLE 7

SUMMARY OF PROBABLE IMPACTS OF THE PROPOSED DIVERSION ON QUABBIN RESERVOIR

Note: This summary does not predict the duration of the impact.

Description of Impact	Relative Probability Impact Will Occur			
	No significant change over existing conditions	Possible but Probability Low	Probable	Probability High
Increase in Nutrient Chemicals			C	
Increase in Eutrophication			C	
Modification of Present Equilibration			C	
Introduction of Undesirable Species				C [1]
Increase in Coliform Bacteria			C	
Increase in Human Pathogens		C		
Interference with Water Treatment at Quabbin			C	
Increase in Levels of Toxic Materials		C		
Increase in Levels of Radioactivity	C			
Increase in Levels of Pesticides	C			
Increase in Extent and magnitude of oxygen depletion			C	

C = Connecticut River Diversion

[1] Assuming exclusion devices were not employed.

B. Millers River Basin Water Supply Project

1) Possible Environmental Impacts of Diversion on the Connecticut River Estuary

As described earlier, contractor services were used extensively in evaluating possible environmental impacts which might occur within the Connecticut River estuary following diversions. In this assessment, a wide range of postulated diversion rates were tested. The diversion rates tested varied from 600 to 4,000 cfs, with adherence to a minimum control flow at Montague City of 17,000 and 12,000 cfs. Only the 17,000 cfs control flow rate has been approved by the Massachusetts Legislature.

The use of the large range of postulated diversion rates, i.e., 600 to 4,000 cfs, with corresponding control flow rates were adopted to allow a full investigation of any potential impacts on the estuary. For example, if the larger postulated diversion rates were tested and limited impact predicted, then the lower diversion rates could be expected to exhibit even less of an impact. This, in fact, is what the results of the study concluded.

All of the minimal impacts on the Connecticut River estuary described earlier for the Northfield Mountain Project would apply also to the Millers River Basin. This similarity is occassioned by the fact that the impacts as described are based on a diversion rate of 4,000 cfs with a control flow rate of 12,000 cfs. Since the diversion rate at Northfield Mountain would be 580 cfs and the Millers River Basin project a maximum of 730 cfs, the total diversion rate would be 1,310 cfs. In addition, both projects are being considered using the higher 17,000 cfs control flow rate, thus the impacts as described are conservative. (i.e. greater than would actually be expected with both projects operating).

2) Possible Environmental Impacts of Diversion on the Connecticut River

Impacts on the Connecticut River downstream from the Millers River Basin project alone in general would be similar to those described for the Northfield Mountain Project. This conclusion is drawn based on the fact that both projects would divert water in the same magnitude of withdrawal rates. (i.e., Northfield Mountain 580 cfs, Millers River Basin 730 cfs).

With both projects in operation, the descriptions of possible impacts; on coliform levels; planned water quality improvements; ground water table and downstream navigation would be similar. Reduction in stage with both projects in operation would be about .37 feet at Montague City and .12 feet at Thompsonville, Connecticut. No significant impacts to downstream wetlands are foreseen for these limited river stage reductions.

Change in concentrations of nutrients which could be caused by both projects operating would be less than .02 ppm. With the implementation of planned waste water treatment plants, this effect would be even less.

Temperature rises in the mainstem of the Connecticut River, based on the loss of dilution flow by both projects, would be about 7% at a maximum. Sediment load transport in turn would be reduced about 6% at a maximum. Downstream from the intakes, flow from intervening drainage areas would cause temperature rises and sediment transport efficiency losses to be even less.

Some increases in flood control protection to downstream communities could be expected with the diversions operating. However, no major increases in protection would occur.

3) Possible Environmental Impacts of Diversion on the Millers River

The effect of diversion on river flow will be most pronounced at the confluence of the Tully and Millers Rivers in Athol, Massachusetts. Up to 55% of the monthly flow may be diverted during an average year. However, in no case would the flow in the river be reduced below the established rate necessary to protect the river environment.

The possible impact of the diversions on ground water recharge was assessed. To aid in this evaluation, the U. S. Geological Survey (USGS) were asked for their expert opinion. With regard to the possible impacts below the Millers - Tully confluence, the USGS stated "Since operation of Birch Hill and Tully Reservoirs prevents overbank flooding, the proposed diversions will have no effect on ground water recharge from flood plains below the reservoirs."

If the diversions were in operation with existing water quality conditions in the Millers River, some degradation of water quality could occur. However, plans for the implementation of secondary waste treatment facilities call for construction of the treatment plants by

1974. Earliest implementation of any of the alternative water supply projects would be in 1981 - 1983. Thus, these facilities would follow construction of the planned secondary treatment plants. The design criteria for these sewage treatment plants is based on receiving water flow during low flow conditions. Diversions, however, would take place during high flow periods; thus, the diversions would not affect the ability of the river to meet adopted water quality standards.

In the Tully - Millers River Plan, the provision of advanced waste treatment facilities to insure water quality suitable for water supply purposes is included. Therefore, the implementation of either of these alternatives would improve Millers River quality over that presently planned. Impact of this project would be an enhancement of the basin's environment through improved water quality.

Because of the total volume of water which would be diverted, a lessening of the sediment transport and "flushing" action normally experienced in the Millers River could be expected. During the 1971 and 1972 spring runoff period, paper pulp in suspension was noted within the Millers River. Apparently, the turbulence associated with high flow can scour some deposits of pulp and carry them downstream, thereby partially cleansing the bottom habitats. Reduction in peak flows from any of the diversion alternatives, if they were operational, now would tend to reduce the effectiveness of this cleansing action. However, the existing uncontrolled flows are not adequate to clean the river. It is necessary to stop the input of pulp before this suspended load can be reduced. After the planned waste treatment described in the previous paragraph is in operation, the pulp load released to the river will be substantially reduced. Since any diversion considered would occur after the waste treatment plants are in operation, any impact of diversion on "flushing" action should be minimal.

Flow diverted by Tully - Millers River Plan may cause a slight temperature difference in the Millers River. Daily fluctuations of temperature in all river systems are most likely far greater than differences noted between tributaries and the river in the same period.

The maximum calculated decrease in river stage at the Main Street Bridge in Athol, Massachusetts, which could be caused by the diversions, is about 1.5 feet. If the basin had a shallow gradient, which it doesn't, such as many of the coastal streams in eastern Massachusetts, such a decrease might have many environmental considerations. A careful examination, however, of the downstream flood plains which would not be inundated due to this decrease revealed limited areas. Therefore, impacts due to decreased river stages which could be

expected on any downstream areas which receive water infrequently are expected to be minimal.

Several cold water species such as trout are now found only in the upstream tributaries while limited species are found in the Millers River itself. Following completion of planned secondary waste treatment and advanced treatment facilities included in the project, fishing opportunities should increase. Diversions would only take place during periods of high flow so that fish passage would not be obstructed by any of the projects during the remainder of the year. In any event, the existing species and any new species would be locked in segments of the river by the existing major dams at Athol, Orange and Millers Falls.

At present, portions of the Millers River mainstem are attractive to the canoe enthusiast.[1] The three reaches of river that would be affected by reduced flows are: 1) South Royalston to Athol, 18 miles described as mostly rapid, very attractive and passable at high water only; 2) Athol to Erving, 11 miles not recommended, mostly smooth and unattractive; 3) Erving to Millers Falls, 6 miles, mostly rapid and very attractive.

Impacts on canoeing in the mainstem Millers River caused by the plan on the three river reaches described above are as follows:

(1) For Reach 1 - South Royalston to Athol, no impacts would occur upstream from the Millers River intake (approximately 16.5 miles). Downstream from the intake, decreased flow may be beneficial during periods of extreme high water; however, diversion may shorten the season on this 1.5 mile reach during lower flow periods in late spring.

(2) For Reach 2 - Athol to Erving, there may be a possible lessening of the available canoeing season. However, this reach is characterized as "unattractive," thus impacts should be limited.

(3) For Reach 3 - Erving to Millers Falls, decreased flow may be beneficial during periods of extreme high water, but diversion may also shorten the season during lower flow periods in late spring. The impact of diversion would be decreased, however, by the contribution of intervening drainage area to river flow.

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[1] A. M. C. New England Canoeing Guide, Published by the Appalachian Mountain Club, 1968 - Vermont Printing Company.

Seasonal inundation of about 15 acres and 1/2 mile of the Millers River mainstem upstream from the diversion intake would be caused by the plan.

4) Possible Environmental Impacts of Diversion on the Tully River

The effect of diversion on river flow will be most pronounced just downstream of the Tully River diversion intake. Up to 74% of the monthly flow could be diverted during an average year. However, in no case would the flow in the river be reduced below the estimated rate considered necessary to protect the river environment.

The possible impact of the diversions on ground water in the Tully River reach downstream to the Millers River was assessed. The U. S. Geological Survey (USGS) were asked for their expert opinion. In response, the USGS stated "Since operation of Birch Hill and Tully Reservoirs prevent overbank flooding, the proposed diversions will have no effect on ground water recharge from flood plains below the reservoirs."

As described in the preceding section on possible impacts in the Millers River, if the diversions were operating now with existing water quality conditions in the Millers River, some degradation might occur. However, as described in the preceding section, the Tully - Millers plan would probably not be constructed until the early 1980's. Existing plans call for secondary waste treatment abatement by the mid 1970's. In addition to these existing treatment plans, advanced waste treatment facilities are included as part of the Tully - Millers River project. Implementation of the existing planned abatement program and the advanced waste treatment plants would provide good quality Millers River water. Impacts on water quality by the project would therefore be minimal.

Because of the total volume of water which would be diverted, temperature changes in the Tully River could be expected. Data collected on the mainstem Millers River and its tributaries, however, revealed daily fluctuations of temperature in excess of differences recorded between the streams themselves. Temperature differentials which could be caused by the diversion of Tully River water, therefore, must be weighed against naturally recurring variations.

The maximum calculated stage reduction in the Tully River, immediately downstream of the project intake, would be about 1.7 feet. The downstream river profile from the intake is fairly rapid to about

one mile downstream. For the remaining four miles of Tully River reach to its confluence with the Millers, the Tully River follows a medium gradient profile with a section of slow-moving water in the Long Pond area. During springtime, some wetlands, primarily in the lower three-mile reach, are subject to inundation. During low flow conditions, the waters recede from these areas and they revert to wetlands. It is possible that the diversion project would affect the duration of the flooding cycle of these intermittent wetlands.

Impacts on the Tully River fisheries downstream from the diversion intake are not anticipated. The Tully River is stocked annually with trout by the Massachusetts Division of Fisheries and Game which provides a "put-and-take" sport fishery. In the determination of the control flow rates used by the Tully - Millers project, the need of these fishing activities were considered. There the rates used were designed to preclude any disruption.

At present, the lower four-mile downstream reach of the Tully River is canoeable; however, the river is characterized[1] as slack and sluggish. Reduced flow caused by the project may be expected to possibly reduce canoeing opportunities. However, because of the nature of the river's gradient, such impacts should be limited.

5) Possible Environmental Impacts of Diversion on Quabbin Reservoir

This study generated and evaluated extensive data on the Quabbin and Wachusett Reservoirs and the Connecticut and Millers Rivers Systems, with the objective of making predictions on the impacts of diverting portions of these riverine systems into Quabbin Reservoir. Field and laboratory data included approximately 100 parameters, including chemical, physical, biological, and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information, and pollution abatement plans were considered and evaluated. Finally, other pertinent data available from both public and private sources, especially on the Connecticut River, were evaluated in the light of the objectives of this study. A summary of this evaluation is given in the following paragraphs.

Central to the evaluation was the development of a qualitative model of reservoir dynamics. If water of lower quality is introduced from a river system into a receiver system, there will most likely be a

[1] A. M. C. New England Canoeing Guide, Published by the Appalachian Mountain Club, 1968 - Vermont Printing Company.

loss in water quality in the receiver system. This loss of water quality is due to various materials in the water. These materials include molecules, ions, suspended inorganic materials, organic debris, and living organisms. One of the central problems of ecology today is to trace the flow of materials from the various compartments of an eco-system.

A major difficulty in evaluating and describing impacts on water quality and ecology which would occur with this plan is the present water quality of the Millers River. As it presently exists, the Millers River water quality is not suitable for diversion as a water supply source. The inclusion of potential diversions from the Millers as an alternative, therefore, is based on anticipated water quality not existing.

This higher quality water is expected following implementation of planned state - federal pollution abatement program and the advanced waste treatment facilities proposed as part of the water supply plans. Since the proposed waste treatment plants would employ a high level of treatment efficiency on pollutants being discharged to the Millers River, a return of the river to its natural background quality could be expected.

As part of the water quality monitoring network established for this report, five stations were sampled on five northern tributaries of the Millers. These tributaries are sparsely settled and not subject to waste discharges. Data collected in the tributaries, therefore, is considered to portray natural background water quality conditions.

The watershed of the various upstream tributaries is a significant proportion of the Millers River drainage area at the diversion intake.

Thus, utilization of upstream tributary data to indicate background water quality in the Millers River after clean-up seems reasonable. Using this approach, a summary of possible impacts of the proposed diversions in Quabbin Reservoir was prepared. These impacts are illustrated in Table 8.

TABLE 8

SUMMARY OF POSSIBLE IMPACTS OF THE PROPOSED DIVERSIONS ON QUABBIN RESERVOIR

NOTE: This summary does not predict the duration of the impact.

Description of Impact	Relative Probability Impact Will Occur			
	No significant change over existing conditions	Possible but Probability Low	Probable	Probability High
Increase in Nutrient Chemicals		X		
Increase in Eutrophication		X		
Modification of Present Equilibration			X	
Introduction of Undesirable Species		X		
Increase in Coliform Bacteria		X		
Increase in Human Pathogens		X		
Interference with Water Treatment at Quabbin		X		
Increase in Levels of Toxic Materials	X			
Increase in Levels of Radioactivity	X			
Increase in Levels of Pesticides	X			
Increase in Extent and Magnitude of Oxygen Depletion		X		

6) Possible Environmental Impact Caused by Added Waste Load of Receivers (Northfield Mountain and Millers River Basin Project)

In keeping with the objectives of the environmental impact statement, the impact which added waste loads, occassioned by the additional water supply, from the projects was also investigated. To provide a measure of the added waste load impact, it was assumed that the environmental cost would be considered as the cost of bringing the quality of water back to its original state. Estimates of providing advanced waste treatment to the incremental water supplied were made. It was assumed that 70% of this additional supply would be treated; the remaining 30% would be lost from the system through evaporation, irrigation and consumed process water. The estimated cost of providing the necessary treatment is 3.4 million dollars on an average annual basis.

In the Project Impact Analysis contained in both the Northfield Mountain and Millers River Basin Water Supply Project reports, this added cost of treatment was included in the evaluation of the projects.

7) Possible Environmental Impacts Caused by Construction of the Alternative Projects (Northfield Mountain and Millers River Basin Project)

The planning phase design of the aqueducts and appurtenant structures of the two projects precludes a detailed assessment of possible environmental impacts associated with the construction phase. If authorized, the recommended projects would undergo detailed design which could alter the preliminary design presented in this report. For example, tunnel shaft locations selected may change, which in turn would affect possible environmental impacts of such construction activities as tunnel spoil disposal, selection of haul roads and maintenance areas.

In response to the possible alterations in design and other followup action which might affect the environment, the Corps of Engineers requires four environmental impact statements for each project authorized. These separate statements are prepared for the Planning, Design and Construction phases, and finally for the Operation and Maintenance stages.

The interim report of survey, for which this impact statement was prepared, is a planning stage report. Detailed data, therefore, are not available on all environmental impacts which might be encountered

during final design and construction of the project. Sufficient information is available, however, to highlight possible areas of environmental concern which would be considered in the followup phases.

All work on the tunnels in the two projects would be underground. Thus, the majority of this construction activity would not be visible or disrupting to the environment. Since the majority of the tunnel routes is in rock of good tunneling quality, the possibility of disrupting local ground water supplies is low. However, the Northfield Mountain hydroelectric facility recently constructed in the region experienced some limited disruption of individual supplies. Therefore, this possibility should be assessed when the final route is selected.

Total rock spoil from tunnel construction of the two projects is estimated to be about 490,000 cubic yards. In the preliminary design, these quantities would require about 10 acres with a 30 foot depth. Spoil from the tunnel, however, is expected to be of good quality and some or all of the material may be recycled into other local construction projects such as road construction. This potential for recycling would depend on final design and other construction activities under way in the vicinity.

Surface construction activities of the tunnels are expected to be limited to the vicinity of the construction shafts and connecting haul roads to spoil areas if needed. Environmental impacts which should be considered in the followup phases include impact on maintenance areas, haul trucks and other associated construction needs.

In summary, detailed environmental impacts of the construction activities associated with the alternative projects cannot be fully described during the planning phase. Possible impacts, however, would be fully described in followup environmental studies conducted in the design, construction and operation and maintenance stages. Although all possible impacts cannot be quantified at this time, sufficient data exists which indicates no major adverse effects from the recommended projects. This conclusion is based primarily on the fact that the majority of construction activities would be underground. Surface construction activities may have potential impacts, but experience with similar projects indicates that such impacts can be minimized through careful planning in the design and construction phases.

8) Possible Environmental Quality Enhancement

a) Environmental Health of Quabbin Reservoir

Environmental health of Quabbin Reservoir is presently in danger. Since 1970, water demands upon the Quabbin system have exceeded the safe yield of the Quabbin watershed. This means that on a long term runoff basis, volume and level of Quabbin will decrease until existing inflows are augmented with new sources. To date, the reservoir has not recovered from the drought of the sixties, although 1972 and the winter of 1972 - 1973 were excessively "wet years" and reservoir levels rose significantly.

Water quality conditions, algal growth patterns in the northern portions of Quabbin suggest that progression toward eutrophication is already taking place there. Water quality in the main body of the reservoir is still of a high quality, but if volumes decrease as projected over the years, the relative masses of high versus low quality water will shift toward an overall loss in water quality. Losses in volume will decrease the natural purification or "treatment plant" capacity and possibly the retention times of inflow waters. Losses in the hypolimnion volume could diminish the managed standing crop of salmonid fishes. The depletion of oxygen in the hypolimnion, whether partial or complete, depends a great deal on quantities of reducing agents in the water. Potential impacts on water quality are manyfold. Iron and manganese may be reduced to the ferrous and manganous state and released to the water column. Sulfate may be reduced to hydrogen sulfide gas resulting in obnoxious gas. In general, then, Quabbin may become unacceptable as a water supply source.

When the waters from the recommended projects are introduced into the system, the yields of the system will again exceed the demand, and levels of Quabbin will increase. With careful management and monitoring, eutrophication can be arrested and the reservoir will continue as a highly acceptable water supply source.

b) Environmental Health in Receiver Communities

Environmental health in the communities to be serviced by the project would undoubtedly suffer without project implementation. Much has been stated previously of the economic and socio economic impacts in the receiver area which would accompany construction of the project. Almost without exception these impacts were of a positive nature, maintaining past progress in improving the quality of life. In addition to these economic and socio-economic gains in the receiver

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area, construction of the project should provide beneficial environmental impacts as well.

Thus, the impact on the environment caused by the recommended project can be viewed from two perspectives. First are those impacts in donor areas on the estuary, Connecticut and Millers Rivers and the receiving water bodies (Quabbin and Wachusett Reservoirs) which would be caused by project implementation. The second perspective is the environmental impacts which would be prevented by project construction. In all cases, possible changes brought about by the recommended project must be viewed in light of the environmental damage which could be expected without the project.

9) Socio-Economic Impacts of the Projects on the Connecticut River Valley

In the evaluation of the socio-economic impacts which the Northfield Mountain and Millers River Basin supply projects may have, two conditions were tested. First, if water was made available to meet 1990 needs; and second, if projects were not constructed. Impacts for both of these situations were then investigated for communities to be serviced by the projects and for those municipalities within the Connecticut River Basin.

Impacts on serviced communities without project implementation are discussed in Section V, under the no-action alternative. Impacts on Connecticut River Basin communities are given in the following paragraphs.

With Project Implementation

1 /Land Use/

In this impact category, both projects would require a total of about 80 acres. Since existing uses are almost entirely limited to undeveloped open space and since acquisition is likely to mean controlled access, the natural character of the taking area will be preserved. In any event, the service population for any of the alternatives is extremely small and significant principally in the eyes of personally affected individuals.

Apart from the recreation issue, the development potential of the host towns with the projects is not thought to be threatened. Given what the towns themselves must recognize as severe geographic disadvantages for industrial growth, it is highly improbable that the

sites needed to implement the diversions would ever have appreciable economic value. Their value is chiefly scenic.

2 /Population/

Beyond the labor influx associated with construction of the projects, it is highly unlikely that current downward population trends will be reversed. In the decade between 1960 and 1970, no town in the immediate supplier area registered appeciable growth; and Winchendon, Athol and Orange experienced net outmigrations of better than 250 persons each. The principal determinant of any population changes related to the diversions proposed will be the recreation issue. Should the development of recreational facilities take place, it is possible that the supplier area could see a slight increase in residential population, though probably only on a seasonal basis.

Construction-phase labor demands will have at least a temporary effect on suppliers, however. To determine how the combined incomes of that work force would be distributed, the experience during construction of the Northfield Mountain Hydroelectric facility was utilized. Though the project was very much larger -- $90 million, employing a total of some 3,700 persons -- the tasks required (such as tunnelling, concreting, carpentry, iron working, pipe fitting, etc.) are of much the same nature as will be required on the diversion works, and project labor is likely to be drawn from the same sources. In a post-audit of the labor force assembled for construction of the pumped storage project,[1] Clark points out that of the 3,368 people employed in the crafts, fully 84% were hired locally; that is, only 16%, or 477 men moved into the area to obtain project work.[2] The great majority already lived within commuting distance and spent their paychecks locally. Indeed, aside from those immigrants who established temporary addresses for the term of their employ (principally hard rock miners from North Carolina, New York State and other extraregional

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[1] "The Labor Force Associated with the Northfield Pumped-Storage Hydroelectric Project and Its Effects on the Surrounding Communities," Frank Clark, University of Massachusetts, January 1971.

[2] The reverse is true for supervisory personnel. Of 355 persons so employed, roughly 60% were immigrants moving to the area for the duration of the project. Most often families were settled in a population center near the project site or in trailer parks in nearby New Hampshire. In terms of spending, however, the same general patterns apply to "wage" staff as to the field force.

areas who were supporting families left behind) salaries were introduced to the economics of Central Massachusetts and southernmost New Hampshire and Vermont. Thus, apart from the purchase of meals and incidentals, the salaries of both professionals and the field force were spent within the immediate region, but outside the borders of the towns sharing the construction site. As for rents, the largest portion of temporary residents was set up in Greenfield or Montague, Massachusetts rooming houses, housing closer to the construction site being virtually unavailable.

Thus, if the projects were "union jobs" and that is the supposition, the same commutation and spending patterns are likely to apply, though at reduced levels.

3 /Municipal Finance/

One other factor seems especially relevant in the determination of economic impacts caused by the projects on supplier areas -- the issue of revenues lost to individual towns because of land absorbed into public holdings and thereby removed from the tax roles. In this particular area of the Commonwealth, tax bases in urbanized as well as rural places are not strongly diversified; and thus, even comparatively minor fluctuations can mean local hardship. Efforts made to detect any significant decreases in collectable revenues were largely unsuccessful. In most cases, local officials were unable to identify exact tract ownerships and relate potential takings to assessments.

Once such a computation can be made, an upper limit to such losses can be established by assuming no compensation. Minimum losses, on the other hand, would occur if either or both the government and the Commonwealth were to make payments in lieu of taxes. Although that is the intention of the latter authority, it is unclear at present exactly what the terms of such an arrangement might be. The Commonwealth has in the past defrayed such losses to communities affected by flood control project takings, and it is not unlikely that special pleading in the legislature will produce the same result again. However restitution is made finally, the objective is to soften the shock of revenue drops and prevent the deterioration of existing municipal services.

4 /Commercial Activity/

With a wide distribution of labor, salary spending should be well diffused, with no one city or town experiencing more than marginal increases in commercial activity. The alternative diversion projects

may absorb whatever labor surplus is created by the completion of the Northfield Mountain pumped storage facility and maintain the employment status quo. Of course, since scheduling is uncertain, unemployment conditions at the time of construction are unpredictable, and it is possible that the Millers Project will come too late to prevent an employment sag caused by the demobilization at Northfield or offer only substitution effects -- paying salaries obtainable elsewhere in a time of full employment. At present, however, unemployment in Massachusetts is in excess of the national average with a rate of 7.5% compared to the national figure of 5.9%. In the immediate vicinity of the alternative projects in Greenfield, Athol, and Gardner, unemployment is even higher that the State total, with figures of 10.1, 7.7, and 8.5%, respectively. Unless, then, employment opportunities prior to construction alleviate these high unemployment totals, the construction activities of any of the alternative would provide substantial opportunities for employment. In any event, the diversion construction could well absorb the fifty-odd local hard rock miners trained at the hydroelectric facility.

Beyond the salaries generated, short-term economic impacts also encompass the monies paid to local residents through land acquisition. Neither the magnitude nor the distribution of such payments is readily available.

From the designs prepared to date, it is clear that land takings will be held to a minimum. Again, as with salaries, benefits to the regional economy rather than to individuals are to be reckoned not just in terms of dollar totals, but by their fluidity. Clearly, when a land seller receives dollars for his land, it makes a difference to the community whether he saves the money, reinvests it, or spends it.

Long-term economic implications for suppliers center largely around the extent to which the volumes of water diverted affect industries now located in the area. As for the first issue, comments made by industry spokesmen at the public meeting held at Athol in late October 1971 indicate a concern for maintaining flows in the Millers River adequate for process purposes. However, it seems safe to conclude that no industrial enterprise will be jeopardized by high flow skimming operations.

5 /Housing/

During the construction period of any of the projects, there will be an increased demand for rental housing. Probably, established urban centers at Greenfield, Gardner and Athol or Brattleboro and Keene

and Hinsdale (trailers) will absorb whatever non-resident labor force appears and that towns nearer construction sites will not be affected. In no event is the stimulation of new housing construction foreseen. Housing prices and property values may rise for the term of construction, but suffer setbacks when the project is completed. Since Greenfield has been identified as an area in which the housing market is sensitive, trends there should be observed as Northfield and Vermont Yankee at Vernon wind down. Adjustments will be required for any data collected to reflect the very much smaller labor force anticipated for this construction job.

6 /Education/

From the experience of a dozen different towns surveyed by Northeast Utilities for effects on school populations,[1] only in one, Hinsdale, was overcrowding attributed to worker influxes. It should be kept in mind, however, that the nuclear generating station at Vernon, Vermont, and increased business activity in Brattleboro account for much of that effect and obscure the influence of Northfield. Other school systems either had no marked increase in enrollments or cited natural growth rather than project in-migration as the cause of crowding.

As a conservative estimate of impacts felt in the supplier area sample of seven communities, we have used one primary classroom or about twenty youngsters. Noting that Greenfield appears to be a primary response area, we have located the demand there and estimate an average teaching staff expenditure of $8,400.

Busing data were not available. However, because the numbers of new school-age children to be served under the situation caused by construction activities is so small and because their distribution would likely be more general than we have assumed -- that is not just in Greenfield alone -- any change in busing costs would be extremely small.

7 /Leisure Opportunities/

Effects in this category are directly dependent on the extent to which present policies on public access to water supply reservoirs and tributary streams may be modified. If present stringent practices were to apply to the Millers diversion, resident sportsmen and occasional

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[1] Bernardston, Deerfield, Erving, Gill, Greenfield, Hinsdale (N. H.), Leyden, Montague, Northfield, Orange, Warwick, Winchester (N. H.).

vacationers may be deprived of outdoor recreational opportunities now enjoyed in the upper Millers River watershed. Based on statements made by Massachusetts Department of Public Health spokesmen, it appears that total isolation will not be necessary.

All this notwithstanding, the perception of local residents is that they will be "cheated" of their inalienable rights to free access.[1] The Quabbin experience has rankled in their minds for some thirty years, and references to an MDC "no-man's land" are not uncommon. Their fears are of total exclusion.

8 /Transportation/

Impacts here are certain to be of a temporary nature. The bulk of construction is to take place below the surface with only small dams, and occassional access shafts at ground level. Mobility patterns in the resident population may change to some degree, but the dominantly rural nature of the area will make such disruptions infrequent.

The construction contemplated will have almost negligible effects by comparison with the recent highway work on Route 2. Heavy trucking will be required for the removal of spoil to fill areas and the delivery of equipment, but intelligent planning can avoid traffic congestion and hazards to residents. Commutation patterns for the work force will have an appreciable effect on the traffic volumes of major arteries. Locations and magnitudes can be reckoned only after the distribution of labor has been established.

9 /Community Image and Cohesiveness/

Impacts forecasted for this category for the projects are very small. No physical separation of populations is involved apart from temporary road closings. No aesthetically undesirable structures are planned, save in the sense that any alteration of the natural scene may be thought of by some as undesirable. Yet, it is in this category that the supply areas themselves feel themselves to be the most injured. Their perceptions of loss are very large, and some commentary seems appropriate.

In terms of standard socio-economic categories like population, density, employment, ethnicity, mobility, etc., and particularly in terms

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[1] One must, of course, consider non-governmental limitations as well. Privately owned, posted land is as unavailable to the general public as reservations, indeed less so in many cases.

of attitudes, the immediate diversion environs are so homogeneous as to be spoken of as an entity. Indeed, in the sense that they share a common interest such as in the disposition of Millers River Basin water, they are a single community whose opposition is unanimous.

Because of the nature of the project under consideration, it is revealing to examine the source of the unanimity. Inhabitants feel that the construction of Quabbin Reservoir in the late 1930's was a shock to the cultural and economic life of the area from which it has never fully recovered. As the testimony of several local people at the Orange hearing indicated, many of the residents of the towns affected by the Millers Diversion Plans consider themselves refugees from the Quabbin site.

Residents of the supplier towns feel themselves to be threatened once again. That is the root of their common cause and the most important cohesive factor in their alliance against the diversion proposed. The social psychology operating here is transference; water for Boston means the bureaucratic machinery of the water supply agency which in turn means wanton despoliation of all that local residents hold dear, and that means a repetition of the upheaval brought by Quabbin in the basin.

Without Project Implementation

In the event that projects are not implemented, the single most important impact in the supplier region will be at Quabbin itself. Biological studies have determined that in the event of a near-complete drawdown, the ecologic viability of the reservoir would be endangered. Moreover, as the water area shrinks, the likelihood of odors and exposure of the unsightly bottom area grows. The recreational opportunities at Quabbin are, therefore, considerably diminished, not to mention the consequences for the receivers of Quabbin water which may change perceptibly in color and taste.

Less dramatic are the direct economic and social impacts on suppliers. First, local stimuli caused by construction activity will be zero. Whatever buffer effect the projects might have had on the labor fallout at Vernon and Northfield and on unemployment in the region will be lost. Whatever dollar gains might have been realized by local economies as a result of labor force spending and landtaking costs will be foregone. It should also be pointed out that the difference between tax revenues collected on property not taken and any payments made in lieu of taxes should implementation proceed could be counted as

"savings." As noted above, however, revenue data have not been made available, and it can only be assumed that the amounts involved are quite small on the order of several thousands of dollars in the three towns directly affected.

Finally, if none of the alternative projects were implemented, whatever monetary value might accrue to the surplus waters not diverted would be returned locally. This eventuality is highly unlikely, however, because there is no reason to foresee the development of new water-dependent industry in the immediate donor area, at least in the 1975 - 1990 time frame.

4. Adverse Environmental Effects Which Cannot Be Avoided Should The Plan Be Implemented

The major impact on the hydrology of the donor systems will be to reduce the peak flows of the rivers during high runoff periods in the spring and sometimes in the autumn. A corollary effect of reducing peak flows, is to reduce the amount of flooded area in the river flood plain downstream. According to the U.S. Geological Survey, recharge of ground water aquifers will not be affected during high runoff periods when diversion would take place since flood conditions are already controlled by Birch Hill Dam and Tully Dam.

During each spring diversion period, about 1-2% of the Connecticut River flow volume will end up in Quabbin Reservoir through the Northfield diversion. An additional 1% would come to Quabbin through the Tully diversions if they were completed. For the spring of 1971, the theoretical figures would have been 1.5% had the Northfield diversion been implemented, plus an additional 0.9% by way of the Tully system. These amounts represent 1% of the total annual flow of the Connecticut River at Montague City. No appreciable impact on the hydrology of the Connecticut River and its watershed downstream from the Northfield diversion site is expected. Berger (1971) has estimated that the Northfield diversion to Quabbin would create a stage reduction of 0.2 foot (2 3/8") at Montague City.

There will be a greater effect on the Millers River system since a larger percentage of water would be diverted during diversion periods, but again no appreciable impact on the hydrology of the Millers River watershed is expected. The diversions may also cause a loss in recreational potential for example, canoeing season could be shortened in the late spring

during low flow periods. The effect of low flows on the Millers during high diversion periods may produce long term subtle changes in the biota of the stream.

A maximum increase in temperature of .61°F can be expected in the Connecticut River estuary for the worst possible conditions under which a diversion would take place, namely a diversion of 4,000 cfs with the control flow 12,000 cfs at Montague. As shown in section 3-A, a 2°F increase would have negligible effects on marine life. Using a control flow of 17,000 cfs at Montague would result in a smaller value for the maximum temperature increase. In either case, these temperature increases are well within the normal temperature fluctuations in the estuary.

Diversion from the Connecticut River will have some impacts on the waters of Quabbin Reservoir. During the first few diversions the turbidity is expected to increase slightly as the Connecticut River water would only account for about 18-19% of the total volume of the reservoir. However, after more diversions as the Connecticut River water makes up more of this total volume, the turbidity could further increase. To insure the acceptability of water diverted to Quabbin water quality monitoring stations would be installed upstream of the diversion point and in Quabbin itself. The location, parameters to be tested and frequency of testing would be established by the appropriate Federal and State agencies. Acceptance or rejectance of water to be diverted during the life of the project would be determined by these health agencies.

As mentioned in section 3-a, the COD level in the Connecticut River is about twice the COD level in Quabbin, thus, after diversion the COD level in Quabbin could increase. This would depend on a number of factors. For one, if the COD is mainly in particulate form, it could settle out and be buried without using any of the available O_2. Some of the COD in the Connecticut River is due to iron and manganese. The iron is already oxidized in the Fe III state and the manganese may also be oxidized. Future pollution abatement plans along the Connecticut River could serve to reduce the COD levels before they reach Quabbin Reservoir.

5. Alternatives to the Proposed Action

During the planning stage of this report, a wide range of alternatives to the proposed diversions were investigated. Included in these alternatives were other possible diversions, use of new technology as a means of augmenting existing supplies, non-structural approaches such as reduction of demand and the evaluation of the no-action alternative. A description of these alternatives and their potential, as solutions to the existing problem, is given in the following paragraphs.

Millers River Basin

Three alternatives were studied within the Millers River Basin to meet the water demands of the expanded regional system. The first is diversion directly from the Millers River above Athol to Quabbin Reservoir. This diversion would result in an average annual yield of 68 mgd and would require advanced treatment of the point sources of pollution on the Millers River, upstream of the diversion site. The second alternative is a combination of one and three. Water would be diverted only from the East Branch Tully River and from the Millers River above Athol, resulting in an average annual yield of 76 mgd. As in the first alternative, advance waste treatment of the pollution sources would be required; but Tully Lake would not be used for water supply storage. Alternative three is the Tully Complex - a series of small diversion works on four tributaries of the Millers River. An average annual yield of 48 mgd is expected with no treatment required before entering Quabbin Reservoir.

As described in Section 1, Alternative No. 2 was selected as the preferred plan for development in the Millers River Basin. Therefore, this section describes the alternative projects considered, i.e., No. 1 - Millers River Diversion, and No. 3 - Tully Complex Diversion.

A. Alternative No. 1 - Millers River Diversion

From the city of Athol extending downstream to the Orange Dam, the setting is a wide level valley with the river meandering through an agricultural setting of pastures, meadows, and settled land. The stream bottom is mud and silt with extensive emergent vegetation as is the outlet of Lake Rohunta which joins the Millers River below Athol. The River is backed up by the Orange Dam about a mile upstream. The zone between Orange and the Connecticut River is typified by steep banks, a sharp river gradient, long rapids followed by

short pools, a complete absence of wetlands, and a boulder strewn rock rubble bottom. Some 22 species of fish are reported for the Millers River watershed. Population magnitude and locations are dependent on the particular species requirements as well as the man-made stress of pollution.

In this alternative, water would be diverted from the mainstem Millers River above Athol, Massachusetts. An inlet structure on the Millers River, a 10-foot diameter tunnel to Quabbin Reservoir and an outlet structure within the reservoir area would be required. At present, proposed pollution abatement plans by Massachusetts State Agencies include secondary treatment on all point sources of pollution on the Millers and Otter Rivers. However, investigations indicate that additional treatment appears necessary to insure a good water supply source and have been included as elements in this alternative.

The diversion site would be located on the Millers River about three miles upstream from the confluence of the Tully and Millers Rivers in Athol, Massachusetts. The structure located in Athol would consist of an inlet to the 10-foot diameter tunnel to Quabbin Reservoir controlled by a combination weir-bascule gate extending across the Millers River. The concrete control structure, 120 feet long, would provide a regulated pool for the inlet shaft. The bascule gate, 70 feet long and 5 feet high, would regulate the water height and velocity to the inlet. The 22-foot diameter morning glory inlet tapering to the 10-foot diameter inlet shaft would be located on the northern bank in the center of a 60-foot square chamber cut in rock. The three 8 x 8 foot gates to the inlet chamber would be opened only when diversions were occurring. By regulating these gates in conjunction with the bascule gates, various combinations of diversion flows and downstream flows can be achieved.

Water diverted from the river would enter the morning glory inlet and drop down the 10-foot diameter vertical shaft into the tunnel. The 10-foot diameter tunnel would run a distance of 7 miles from the Millers River inlet to a point south of Gays Hill on Quabbin Reservoir. The tunnel would be excavated in rock by mole methods and lined with concrete to a finished diameter of ten feet.

An analysis was made of the present and projected loadings of waste discharges upstream from the diversion intake, present and planned treatment, and present and planned waste effluents. Based on available information, further treatment would be required to insure a good quality water for diversion. Our studies indicate that tertiary

treatment at the source of pollution is preferred to water treatment at the Millers River intake. The final determination of this additional treatment will be made during the Design Phase. By that time, the planned secondary treatment plants will probably be in operation and the effectiveness of these plants will be known. Also, then, the effect the existing sludge banks will have on the water quality can be measured. It is expected that once the load on the river is minimized, the natural flushing action will wash away large amounts of sludge in the Millers and Otter Rivers resulting in a relative stable water quality.

The operation of this diversion would depend first on the flow in the Connecticut River as measured at the U. S. G. S. gaging station at Montague City, Massachusetts; and secondly, on the flow in the Millers River at the diversion site. On any given day, the flow in the Connecticut at Montague City would be checked to see if the flow is above 17,000 cfs. If it is not, then no diversion would occur. If it was above the 17,000 cfs, then the flow in the Millers River at the diversion site would be checked. If the flow in the Millers River is less than the flow determined to be required for the river and its environment, hereafter referred to as the control flow, then no diversion would occur. This control flow was determined from flow requirements for: assimilation of wastes; for fish and wildlife and is related to the time of year and the drainage area. The following table shows the control flows at the Millers River intake:

TABLE 9

MILLERS RIVER CONTROL FLOW AT INTAKE

	Jan Feb Mar	Apr May Jun	Jul	Aug	Sep Oct Nov	Dec
CSM	0.5	1.25	2.0	1.0	0.75	0.5
CFS	100	250	400	200	150	100

If the Connecticut River flow is above 17,000 cfs and the Millers River flow is above the control flow for that day, then diversions would occur. In no case would water be diverted lowering the flow in the river below the control flow. But neither would the flow be augmented if it was naturally below the control flow. So, the rate of diversion on any given day could vary from zero to the maximum capacity of the tunnel, 730 cfs.

The total project cost is estimated to be 36 million dollars based on May 1972 price levels. All costs include an allowance for contingencies (20 percent), engineering and design, and supervision and administration. The estimated costs are based on knowledge of the sites and experience on similar projects. Evaluations of property are based on real estate studies and information from local officials, reflecting values in recent sales in the area.

Impacts on the Connecticut River estuary; the Connecticut, Millers and Tully Rivers downstream from the diversion intake; and Quabbin Reservoir would be similar to that described in Section B for the Tully-Millers River Diversion.

B. Alternative No. 3 - Tully Complex Diversion

The Alternative No. 3 plan for making diversions from the Millers River Basin involves the construction of an 8-foot diameter tunnel from Tully Lake to Quabbin Reservoir, a dam on Priest Brook, and diversion structures on Tarbell Brook and West Branch Tully River. Water would be diverted in a pressure conduit from Tarbell Brook to the proposed Priest Brook ponding area. Pumping facilities at the Priest Brook Dam would convey this water together with Priest Brook water to Tully Lake. A gravity feed tunnel would then divert the two brooks' water plus the East Branch Tully water out of the basin to Quabbin Reservoir. Water from the West Branch Tully could then be pumped into the tunnel near the confluence of the East and West Branches of the Tully River. Recreation and wildlife management programs are also included at these diversion sites.

1) Tarbell Brook Diversion

Tarbell Brook is a small, low gradient stream approximately 7-1/2 miles long from its headwaters to its confluence with the Millers River. Open water areas (which include lakes and ponds) along the stream cover 1-1/2 miles. The total drainage area is approximately 27 square miles of which about 5 are wetland, less than 2 are open water, and the remaining area representing upland habitat.

Flow is moderately rapid through forested areas and slow in open wetland areas. Stream width varies up to 30 feet. Depth is variable and measures several feet in some places. Water quality is good (Class B). The adjacent habitat is primarily coniferous forest combined with mixed stands of hardwoods.

The stream is stocked annualiy with trout by the Massachusetts Division of Fisheries and Game which provides a "put-and-take" sport

fishery. Several species of game such as woodcock, grouse, black duck, rabbit, squirrel, and deer inhabit the area.

The proposed diversion site would be located on Tarbell about 1/2 mile above its confluence with the Millers River and approximately 2-1/2 miles northwest of Winchendon, Massachusetts.

If implemented, the project will seasonally inundate 40 acres of wetland habitat to a depth of 5 feet, including 1/2 mile of free flowing stream.

2) Priest Brook Diversion

Priest Brook, including Scott Brook, (its main northern tributary) extends approximately 14 miles from its headwaters in southern New Hampshire to its confluence with the Millers River. Open water areas cover one mile along the stream which is of moderate to low gradient and flows through forested and wetland areas. Width varies up to 40 feet and depth is variable, generally three feet, but as much as six in some areas.

The total drainage area is approximately 23 square miles of which about three are wetland, less than one is open water, and the remaining area is upland habitat. Water quality is good (Class B) but below average for trout during summer months due to high temperature and low flow conditions. Adjacent habitat consists of coniferous forest with mixed stands of hardwoods.

This stream is stocked annually with trout by the Massachusetts Division of Fisheries and Game which provides a "put-and-take" sport fishery. Waterfowl and other game species are essentially similar in type and number to that found in the Tarbell Brook watershed.

The proposed diversion site would be located approximately four miles due east of the town of Royalston in an unpopulated area, three miles above the confluence with the Millers River. The project area will encompass about 400 acres, including approximately 330 acres of wetland and 70 acres of upland habitat.

The following private developments are located within the project area: an extensive private camping development consisting of approximately 50 trailers and attendent facilities and a gun club facility including a clubhouse, target range, and a one-half acre pond, just north of Winchendon Road, and a major tree farm.

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If implemented, the 400-acre site will be cleared and seasonally inundated, including all of Priest Brook above the proposed damsite, and short reaches of Scott and Town Brooks. The entire project area will be subject to periodic inundation and drawdown. During certain times of the year, natural stream flow into the Millers River would be reduced.

3) Tully Reservoir Diversion

The East Branch Tully River extends about 15 miles from its headwaters in southern New Hampshire to its confluence with the West Branch Tully River. Open waters along the stream, including Tully Reservoir, cover 6 miles. The total drainage area of this river is 56 square miles of which about 8 are wetland, 6 are open water, and the rest upland habitat.

The river is of medium gradient with a section of slow moving water in the Long Pond area. Width varies up to 30 feet and depth up to 8 feet in some areas. Water quality is good (Class B) and is classified as "good trout water" on a seasonal basis. Terrain surrounding the river is moderately steep and heavily forested with mixed deciduous and coniferous trees.

The East Branch of the Tully River is stocked annually with trout by the Massachusetts Division of Fisheries and Game which provides a "put-and-take" sport fishery. Waterfowl and other game species are typical of those found in the Tarbell and Priest Brook Watersheds. Considerable hunting activity for birds, small animals, and deer takes place in the basin. Numerous wood roads and trails remaining from past logging operations provide good access for hunters and fishermen. Recreation development potential is excellent; canoeing occurs below Tully Dam during periods of high water.

The proposed diversion site would be located within the existing Tully flood control reservoir. The existing pool forming Tully Lake would be doubled, increasing the present surface area to 620 acres during the summer recreation season. The pool would subsequently be gradually drawn down after Labor Day. Since Tully Lake would become a domestic water supply source, it appears necessary to clear and strip organic material on the bottom in order to protect the water quality.

With the proposed plan of diversion from Tully Reservoir to Quabbin, up to 25 percent of the storage capacity of Tully will be used for the

dual purpose of flood control and water supply. During the spring freshet season, this storage will be filled if, and when, inflows exceed downstream requirements and diversion capacity. This stored water will later be diverted to Quabbin, making the full flood control storage capacity of Tully available for the fall hurricane season.

4) West Branch Tully River Diversion

The West Branch Tully River, including Tully Brook, north of Sheomet Lake, is about 8 miles long, extending from its headwaters in central northern Massachusetts to its confluence with the East Branch Tully River, 1-1/2 miles north of Athol. The West Branch is of a moderate gradient, and is up to 35 feet wide with depths up to 5 feet along its course. Open water areas, mainly Sheomet Lake, cover only 1/2 mile along the river. Water quality is good (Class B) and the river is annually stocked with trout by the Massachusetts Division of Fisheries and Game. Total drainage area of the basin is about 19 square miles of which approximately 2 acres are wetland and the remainder upland.

The river flows through a relatively unpopulated and heavily wooded (mixed conifer and deciduous) area. Wildlife found in this basin is similar to that of the nearby East Branch Tully, Priest, and Tarbell Brook areas.

The proposed diversion site would be located two miles north of Athol, in the town of Orange. It would be on the West Branch Tully River about 500 feet above the confluence with the East Branch Tully River, and about 1-1/2 miles above the confluence with the Millers River.

This water supply plan for diversions from the Millers River Basin involves the construction of an 8-foot diameter tunnel from Tully Lake to Quabbin Reservoir, a dam on Priest Brook, and diversion structures on Tarbell Brook and West Branch Tully River. Water would be diverted in a pressure conduit from Tarbell Brook to the proposed Priest Brook ponding area. Pumping facilities at the Priest Brook Dam convey this water together with Priest Brook water to Tully Lake. A gravity feed tunnel would then divert these two brooks' water plus the East Branch Tully water out of the basin to Quabbin Reservoir. Water from the West Branch Tully could then be pumped into the tunnel near the confluence of the East and West Branches of the Tully River. Recreation and wildlife management programs are also included at these diversion sites.

The Tarbell Brook diversion site is located in Winchendon, Massachusetts, about one-half mile upstream of the confluence of Tarbell Brook with the Millers River. The structure consists of a 75-foot long weir and pumping station. A 28-acre pool with a maximum depth of nine feet would be formed by the weir with a top elevation of 840 msl. The inundated area would be cleared and grubbed to improve its appearance. Water would be drawn from the pool and pumped through a 42" diameter pressure conduit running beside Royalston Road to the Priest Brook ponding area. The pumps and pipeline would be designed to carry a maximum of 90 cfs.

The Priest Brook Dam is located on the Winchendon - Royalston town line, just south of Winchendon Road, some 2-3/4 miles upstream from the confluence of Priest Brook with the Millers River. The pool at spillway crest would have a surface area of 400 acres and a maximum depth of 30 feet. The inundated area downstream of Royalston Road has to be stripped or covered with a gravel blanket to prevent degradation of the water. A weir located upstream of Royalston Road would form a 40-acre wildlife pool. Regulation of this pool would occur during the summer and fall to maintain a shallow depth of water (approximately 5 feet). The 45-foot high main dam buffers the river flow and as such the pool is intermittently filled and emptied inundating the permanent wildlife weir.

A pumping station located at the outlet would divert up to 120 cfs through a 72-inch pressure conduit to Tully Lake. The pressure conduit will run west beside Winchendon Road until it intersects a power line running northwest. Then the conduit follows this easement to Long Pond on the East Branch Tully River.

The diversion site on the East Branch Tully River is located at the outlet of the existing Corps of Engineers Tully Flood Control Reservoir. The existing outlet channel would be enlarged and a morning glory intake structure and a 7-foot high modified bascule gate added. Only two inches of the 8.3 inches of run-off storage in Tully would be utilized for reregulating flows for diversion to Quabbin Reservoir. During the summer a recreation pool would be held at elevation 648 msl and no diversions from Tully would occur. In order to improve the water quality, the 620 acres inundated would be cleared, grubbed and stripped. Water diverted would enter the morning glory inlet and drop down the vertical eight-foot diameter shaft into the tunnel. The eight-foot diameter tunnel would run horizontally at elevation 300 msl for some 2.2 miles to the entrance shaft from the West Branch Tully River diversion.

The West Branch Tully River diversion site is located about 800 feet upstream of the confluence of the East and West Branch Tully River. The structure consists of a 320-foot long, 25-foot high earth filled dam with a 50-foot wide spillway, a water intake chamber and a pumping station. A permanent 13-acre pool would be formed by the dam to divert from and for wildlife habitat. A maximum of 90 cfs would be pumped from this pool to the intake shaft through a 30-inch diameter pressure conduit.

The water entering the eight-foot diameter tunnel would join with the flow from Tully Lake running in an 8.6 mile, eight-foot diameter tunnel from the outlet of Tully Lake to a point south of Gay's Hill on Quabbin Reservoir. The tunnel would have a maximum capacity of 390 cfs.

The water quality studies conducted prior to 1971 on the Tully Complex streams were limited basically to summer analysis for pollution abatement. These studies were augmented by our own to determine the water quality of the streams.

The physical and chemical analysis of these waters revealed that no treatment would be required prior to the entrance of this water into Quabbin Reservoir near Gay's Hill. The storage time and dilution provided within Quabbin would result in a good quality water. These streams have a natural color to them from the many swamps within the watershed. Otherwise, the streams would be of excellent quality. This water will not have environmental or public health stress on Quabbin Reservoir; and therefore, does not require either waste or water treatment before entering the reservoir.

As in the other two alternatives, the operation of this diversion would depend first on the flow in the Connecticut River. If the flow in the Connecticut at Montague City is above 17,000 cfs, then the flows at each diversion site would be checked. If the flow at each site is less than the flow determined to be required for the river and its environment, then no diversion would occur. This control flow was determined from flow requirements for assimilation of wastes; for fish and wildlife; and is related to time of year and the drainage area. The following table shows the control flows at the individual diversion sites:

TULLY COMPLEX DIVERSION CONTROL FLOW AT INTAKES

	Jan Feb Mar	Apr May Jun	Jul	Aug	Sep Oct Nov	Dec
CSM	0.5	1.25	2.0	1.0	0.75	0.5
CFS						
Tarbell	12.8	32.0	51.2	25.6	19.2	12.8
Priest	9.7	24.3	38.8	19.4	14.6	9.7
E. Br. Tully	25.2	63.0	100.8	50.4	37.8	25.2
W. Br. Tully	9.3	23.3	37.2	18.6	25.2	9.3

If the Connecticut River flow is above 17,000 cfs and the flow in the specific diversion site is above the control flow for that day, then diversion would occur from that one diversion site. In no case would water be diverted lowering the stream flow below the control flow, but neither would the flow be augmented if the natural flow is below the control flow.

The total estimated project first cost is 41 million dollars based on May 1972 price levels. These costs include an allowance for contingencies, engineering and design, and supervision and administration. The estimates are based on knowledge of the sites and experience on similar projects. Evaluations of property are based on real estate studies and information from local officials, reflecting values of recent sales in the area.

Impacts on the Connecticut River Estuary; the Connecticut, Millers and Tully Rivers downstream from the proposed intake; and Quabbin Reservoir would be similar to that described in Section 3 for the Tully-Millers River Diversion.

The impoundments included in this alternative present other problems.

Tarbell Brook Diversion

If implemented, the project will seasonally inundate 40 acres of wetland habitat to a depth of 5 feet, including 1/2 mile of free flowing stream. The weir would prevent free movement of stocked fish as well as resident species. Diversion of natural high flows may reduce canoeing potential.

Priest Brook Diversion

If implemented, the 400 acre site will be cleared and seasonally inundated, including all of Priest Brook above the proposed damsite, and short reaches of Scott and Town Brooks. The dam would prevent free passage of stocked fish as well as resident species. The entire project area will be subject to periodic inundation and drawdown. During certain times of the year, natural stream flow into the Millers River would be reduced. A 40 acre waterfowl pool would be made possible by the creation of a low weir above Deland Road.

Potential for recreational opportunities within the project area would be limited to hunting, fishing, hiking, nature study, etc.

Tully Reservoir Diversion

The proposed diversion site would be located within the existing Tully flood control reservoir. The existing pool forming Tully Lake would double the present surface area to 600 acres during the summer recreation season. The pool would subsequently be gradually drawn down after Labor Day. Since Tully Lake would become a domestic water supply source, the lake bottom would be cleared and stripped of organic material in order to protect the water quality.

With the proposed plan of diversion from Tully Reservoir to Quabbin, up to 25 percent of the storage capacity of Tully will be used for the dual purpose of flood control and water supply. During the spring freshet season, this storage will be filled if, and when, inflows exceed downstream requirements and diversion capacity. This stored water will later be diverted to Quabbin, making the full flood control storage capacity of Tully available for the fall hurricane season.

Flood control storage requirements are the greatest in southern New England during the fall hurricane season and secondly in the spring during the snowmelt season. As a result, in some Corps reservoirs in New England, some seasonal encroachment on flood control storage has been recommended for other worthwhile uses.

If implemented, the proposed project would cause periodic inundation of 300 acres of wetland, which are presently subject to seasonal inundation during natural flood conditions. High flows below Tully Dam during the spring would be reduced. Following the fall drawdown, some lake bottom would be exposed. Recreation development potential for summer day use facilities is high with excellent opportunities for various outdoor activities. Less than 50 acres of upland game habitat would be lost, while fishing and boating values associated with this project would increase.

The environmental impact on the proposed diversion site would be essentially the same as at Tarbell Brook. About 13 acres will be permanently inundated, which includes 1/2 mile of free flowing river. This 1/2 mile stretch of trout stream would be replaced by a marginal waterfowl area. Recreation opportunities would remain limited after implementation of the proposed diversion plan.

Diversion is not expected to significantly affect sport fishing above the confluence with the Otter River. The sport fishery is presently located primarily upstream of the diversion sites and the amount of diversion expected from Tarbell Brook is insignificant compared to the total water volume available in the mainstem of the Millers River.

Effect of diversion on white-water canoeing may be beneficial during periods of extreme high water; however, diversion may shorten the season during low-flow periods in late spring. Diversion would have no effect on canoeing above the confluence with Tarbell Brook.

For alternative No. 3, the pool formed on East Branch Tully River and Priest Brook would be subject to fluctuation. For example, the entire pool in a normal operation may be filled and emptied within a period of less than 3 months. Under such pool fluctuations, the possibility of erosion does exist. These fluctuations, however, are not expected to cause bank sloughing. The erosion instead would be similar to roadbank erosion caused by surface runoff.

Diverting maximum design capacity of 90 cfs from Tarbell Brook and 30 cfs from Priest Brook will affect the stage of the streams below the diversions less than a foot. Nearly all riparian rights along the reaches of Tarbell and Priest Brooks affected by the proposed diversion are controlled by the Corps of Engineers Birch Hill Dam.

Since operation of Birch Hill Reservoir and Tully Reservoir prevent overbank flooding, the proposed diversions will have no effect on groundwater recharge from flood plains below the reservoirs.

Skimming flood flows from Tarbell and Priest Brooks to Tully Reservoir will have no effect on stream flow above the points of diversion, so there will be no change in overbank flooding.

Impoundments present other problems. Shallow ponds, such as those proposed for the tributary streams, tend to reduce the quality of water impounded in them. Water temperatures are increased, algal populations tend to bloom, and dissolved oxygen depletions occur as the algae blooms decline. The short-term outlook for water quality in the impoundments is a decline in quality. The long-term (20-year) projection is definitely toward lower water quality from the impoundment areas.

In general, the longer the retention time, the greater the probability of ecological changes towards the lentic condition. Although specific changes in the ecology of a single impoundment are difficult to predict, it is reasonable to assume that the ecological changes in the impoundments at Tarbell Brook and the West Branch of the Tully River will progress more closely towards a relatively stable lentic condition than will those at Priest Brook, for example. Thus we visualize a whole range of ecological changes in the impoundments..

No Action

In the evaluation of this alternative, it was assumed that any failure to implement additional supplies for the study area would cause socio-economic impacts on serviced communities. To verify this assumption, a quantification of these impacts was necessary.

Estimates of impacts caused by a no-action policy can be expressed in two different ways. First, concrete losses without the diversion total $84 million to 1990 and $738 million to 2020 if average runoff conditions prevailed. Under drought conditions, concrete losses without diversion total $146 million to 1990 and $835 million to 2020.

Categories included in these totals encompass industrial, city emergency, city, revenue: commerce, sprinkling, business investment and domestic investment losses. However, economic losses in these categories say nothing of the ways in which the losses might be allocated. For example, of the approximately $3.5 million not collected in city revenue in 1990 by all receivers under a no-action policy, there is no way of knowing whether it would be municipal expenditures on recreation or schools that might suffer. This loss in revenue was expressed as 600 classrooms. Similarly, housing units not built are but an alternative manifestation of losses in the private sector.

Social impacts in communities serviced by the supply system under a no-action alternative would be principally "shadow costs" of the concrete losses. To assess the impacts of such shadow costs on the sixty-six receiver communities, the experience of an actual municipality already beset by the kinds of problems anticipated in the event of prolonged water shortage was evaluated.

The town selected for examination was Stoughton, Massachusetts, an industrial - residential community in the Brockton S. M. S. A. An extended interview with Stoughton's Planning Board Chairman produced both background and impact information. Growth in the town has been steadily upward and shows no sign of a downward turn. The principal constraint on continuing growth may be an acute shortage of water.

The town has been searching for water since 1955 and results have been disappointing. The consequences of the resulting water deprivation have been felt across a wide range of community activities.

Although no shifts in the allocations of land use type have occurred, development in the industrial category has been nearly stopped by water shortage. Economic development has been hurt because water using industries have been turned away. This has slightly decreased the stability of the town because the tax base has not expanded quickly enough to keep up with the demands on local revenue. Wages and prices have remained in phase with the rest of the state, but taxes have increased. No Stoughton industries have left because of water shortage, but new industries have gone elsewhere. Presently, only non-manufacturing, non-processing firms are permitted to locate in town, and a $40 million industrial park is now two years behind in its development schedule.

While data projections estimated in this report show population deficits without the provision of additional supply, it does not appear, based on the Stoughton experience, that population growth is sensitive to short term controls and constraints. Stoughton's in-migration continued despite the building ban and shows signs of g wing even more quickly now that new housing construction has begun again. Since the lifting of the building ban, over 500 rental units have been built and occupied. The demand for housing has lowered the vacancy rates significantly and stimulated the construction of 3,000 apartment units and the planned development of 3,000 more. Before the ban went into effect, issuances of building permits had declined for two successive years.

Because finding water has been a top town priority, other municipal services have suffered. A sidewalk program has been indefinitely

postponed, and only minimal roadway maintenance and construction have occurred. Generally, expenditures have been cut as revenues from expected property tax have dwindled. Estimates range as high as $1,000,000 in tax losses with increases in assessments covering the deficit. The cost of water has doubled in the past two years, and the municipal debt as of 1 January 1970 stood at $320 per capita. Until a mutual help agreement was reached with Easton and Sharon, adequate fire protection was a critical concern. A much needed junior high school has been put off -- an effect attributed to the "extraordinary high expenditures of finding water." As a result, the present junior high is now in double sessions.

As the search for water has become business as usual, citizens appear to have developed some tolerances for the inconvenience of watering bans. However, their latent insecurity about adequate supplies for fire protection and general domestic consumption have made water shortage a perennial political issue on which concern can focus.

Despite the general slowdown in industrial development and its second order consequences on town revenues, the average citizen perceives the water supply problem in terms of his own inability to water outdoors. Lawns and shrubbery are a waste of money, says the homeowner, and the town looks poorer for it. In turn, these feelings are reflected in attitudes about the desirability of the community as a place to live and work.

In addition to socio-economic impacts, a second major impact could occur with the no-action alternative. This second impact regards the probable deterioration in water quality within Quabbin Reservoir which could be caused by lowered reservoir volumes. Quabbin Reservoir presents a complex limnological situation. Some areas of the reservoir, such as the northern sections appear to be progressing toward eutrophication. In the main reservoir body, however, quality is still high. If the pool volume decreases over the years as might occur with the no-action alternative, then there will be a shift towards an overall loss in water quality in the reservoir. Losses in volume will decrease the "treatment plant" capacity and hypolimnion volumes affecting water quality from both an environmental and public health standpoint.

Based on the evaluation of the socio-economic and environmental impacts, the no-action alternative has many disadvantages. Use of this alternative, therefore, does not offer a realistic solution to the short range needs of the study area.

Weather Modification

The primary source of the water used for public and private water supply in Massachusetts, as in most humid areas, is precipitation falling directly on the areas concerned. It follows then that if precipitation can be increased in a regulated manner, the water supply can also be increased. To this end, several major agencies such as the National Oceanic and Atmospheric Administration (NOAA), the United States Bureau of Reclamation, the American Meteorological Society, and the National Science Foundation are investigating ways of productively modifying natural precipitation patterns. The primary focus of research is in the area of cloud seeding. Other fields of interest are long-term seasonal precipitation forecasting and fog drip augmentation. Since little work has been done on the latter two, and what little has been accomplished is not applicable to the Massachusetts area, only the process of cloud seeding will be reviewed in this section.

A. Cloud Seeding

Simply stated, rain falls from clouds when water vapor in the clouds condenses around nuclei and forms rain drops large enough to overcome frictional resistance to falling. In technical terms, this process is the conversion of the water vapor from a state of colloidal stability to one of colloidal instability. The concept of artificially induced precipitation by cloud seeding refers to the introduction of particles of foreign substances, such as dry ice and silver iodide into clouds to serve as condensation nuclei. Theoretically, this action will result in condensation of the water vapor and consequent precipitation. In short, it is scientific rain making.

The testing of the engineering and economic feasibility of this theoretical process has been concentrated in experimental projects in the Rocky Mountain and Upper Great Plains regions. Evidence gained through NOAA research suggests that winter cloud systems over Lake Erie may be modified to produce additional precipitation. A cost benefit study was performed for the Connecticut River Basin, but this study was in design only with no actual experimental work involved. Most information regarding the potential of cloud seeding in the eastern United States is derived from commercial cloud seeding operations.

Some of the findings resulting from these studies and experiments are summarized below:

1) The state of the art is such that most researchers look upon the potential of increased precipitation through cloud seeding with

an air of cautious optimism. Study to date, however, has provided little more than a beginning to the solution of many of the problems involved in weather modification.

2) Cloud seeding is impractical during severe drought conditions when water shortages are most critical. The first requisite for cloud seeding is the presence of clouds, and droughts are notable for their lack of clouds. Present technology is not even remotely capable of producing clouds by weather pattern modification. During a temporary interruption of drought conditions, clouds may form over an area. Even under these conditions, however, cloud seeding would not appreciably alleviate water supply problems since most precipitation would be in all likelihood taken up immediately by plants and soil. It is apparent then that water shortages in periods of drought cannot be solved by cloud seeding. Any substantial seeding induced precipitation would have to be produced during non-drought conditions with abundant moisture in the atmosphere.

3) There are many problems that must be solved before substantial technological breakthroughs result. One of the most critical is the inability of researchers to satisfactorily define optimum cloud conditions and seeding techniques and to predict seeding results accurately. In other words, there is an inadequate understanding of the basic cloud processes which determine: a) the "seedability" of a cloud or cloud system, and b) the proper seeding treatment to stimulate rainfall production efficiently in a potentially seedable cloud.

Another problem is the possibility of undesirable effects of seeding. Indiscriminate seeding might increase soil erosion and sedimentation in streams through intensification of the normal rainfall rate of natural storms. There is the possibility also that artificial seeding of clouds might in fact reduce the natural rain producing capacity of the clouds.

4) Estimates of the feasibility of cloud seeding in the eastern part of the country, including New England, are vague and poorly defined. Most recent cloud seeding research has been conducted in the western states. Atmospheric scientists have cautioned that results of seeding experiments in one area of the country must be viewed with caution when applied to other areas characterized by different topography and climate. It is apparent that much research needs to be done in the eastern part of the country. There is data available for parts of this area from commercial cloud seeding operations. However, these operations were not performed under proper scientific and statistical control procedures and any data gathered in such a manner must be used and interpreted with care.

B. Conclusion

Research has continued to improve the state of the art of weather modification by cloud seeding and other means. At best, however, weather modification is still an inexact science. Studies are unable to predict optimum cloud conditions and seeding results with any degree of accuracy. It is the conclusion of this section, therefore, that at this time weather modification operations to augment water supplies in Massachusetts does not appear to be a viable solution to the immediate water supply problem.

Desalinization

Desalinization, the process in which brackish and salt water is converted to fresh, is currently being used in some parts of the world as a viable, economically feasible source of fresh water. This process thus was considered for its potential as a future alternative solution to the water supply needs of eastern Massachusetts.

The conversion of saline to fresh water is accomplished through four major processes: distillation-evaporation, membrane separation, crystallization, and chemical differentiation. A descriptive summary of each process is given below.

A. Distillation-Evaporation

In this process, water containing salt or other impurities is heated and vaporized. The water vapor, free from the salt and other solids which remain behind as the water boils, is then condensed and collected. The system is basically a simple one requiring only a source of heat energy to boil the water, a method of cooling the water vapor (condensation) and various kinds of plumbing and receptacles for the transfer and storage of the water.

Since distillation, by its nature, results in the complete separation of the water vapor from the dissolved salts of the influent, the process produces fresh water of exceptional purity. Because this method removes the water from the salt, rather than vice versa, the quality of the influent is not critical and the system works equally well on water with a high salt content as an only slightly brackish water. For these reasons, among others, distillation is the oldest and best-known process of desalinization.

B. Membrane Separation

Desalinization by the membrane process is based upon the ability of thin membranes to pass molecules of pure water and retain the ions of salts and other dissolved solids. There are three basic variations to this concept: a) electrodialysis, b) transport depletion, and c) reverse osmosis. The first two variations depend on the electrical properties of the ions involved, while the third depends on a pressure differential existing across the membrane. Of these three variations, the electrodialysis process is the most well established, with many commercial installations throughout the world.

In contrast to distillation, the membrane process separates the salt from the water rather than the water from the salt. Each stage of the electrodialysis process removes slightly less than 50% of the dissolved solids in the water being treated. The more saline water, the more stages are needed and hence more energy is consumed. For this reason, electrodialysis and other variations of the membrane process are more economical when used with brackish water with a salinity of between 5,000 - 10,000 mg/l, as opposed to more saline water. The water can then be refined in stages to the desired degree of purity.

C. Crystallization

This process relies primarily upon the fact that as water freezes, the ice crystals reject ions of salt. Saline water is frozen and the crystals of pure ice are then skimmed or removed for later use from the still liquid brine. A second method of separation by crystallization employs the hydrate process which is the formation of a crystalline substance by the combination of water with low molecular weight, hydrocarbons or their derivatives. Like ice crystals, these hydrates reject salt ions. It takes less energy to freeze water than it does to boil it, thus this method has an advantage over distillation in that it consumes less energy. The crystallization process has not been widely used, however, and further research into its effectiveness is continuing.

D. Chemical

In this process either the water or the dissolved salts are made to undergo a chemical reaction which forms a substance which can be easily separated from the untreated water. Ion exchange, a method by which the saline water is passed through treated resin and the salt ions selectively removed, is the most widely used method of chemical desalinization.

The efficiency of ion exchange decreases with time as the "holes" in the resin become filled with salt ions. Once the resin is saturated, the operation must be closed down and the resin regenerated. For these reasons, the process has had only local exposure and small volume use.

E. Present Application

Sea water can be considered, for all intents and purposes, an unlimited source of fresh water once the technology of desalinization is refined to a point where it is economically feasible. To this purpose, the federal government, through the Office of Saline Water, has promoted extensive study and research into the problems of desalinization. Several model and testing plants and facilities have been constructed to aid in these

studies. The research to date concludes that of the four main processes discussed above, distillation and membrane separation are best suited to large capacity plants. Economical considerations dictate that distillation is best for sea water and electrodialysis for brackish water.

Presently more than 300 million gallons per day (mgd) of desalting capacity is installed world-wide. Plants are generally located in arid regions where conventional water sources are high cost or unavailable. Principal areas of use are in the Mid-East and Caribbean tourist islands. In the United States, desalting for municipal water supply has thus far been limited to smaller communities, relatively isolated from sources of conventional supply.

The largest municipal desalting plant in the United States is a 2.6 mgd distillation process in Key West, Florida. Largest in the world is a French-built, 30 mgd distillation plant, recently completed in Kuwait.

A distillation plant was recently proposed for San Louis Obispo and Santa Barbara Counties, California, which would have a capacity of 40 mgd. Construction on this plant which would have been the largest in the world was scheduled to begin in 1973, however, action on this plant has been recently suspended.

F. Costs of Desalinization

The cost of fresh water produced by desalinization depends upon the capacity of the plant, the type of process used and whether nuclear or fossis fuel is used. In general, the larger the plant capacity, the less the cost per unit of water. As has been mentioned previously, distillation is more economical for the desalting of sea water, while electrodialysis is better for brackish water. The water costs from nuclear fueled plants are approximately 10% less than from fossis fuel when used in large capacity (more than 100 mgd) plants.

The current cost of desalting is about one dollar per thousand gallons. This estimate is based upon an output capacity of 1 mgd, an amount representative of many plants currently in operation. Designs for the larger plants, such as for San Louis Obispo and Santa Barbara Counties, California, indicate costs in the vicinity of 73 cents per thousand gallons at the plant site. To this figure must be added delivery system costs.

G. Conclusion

Desalinization by numerous processes is already feasible in parts of the world when the natural water supply is either scarce or of poor quality. In these areas, the relatively high costs of water produced

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by desalinization are justified. Research [1] has indicated that when larger capacity plants are designed and in production, the costs for desalting sea water could ultimately be reduced to approximately 50¢ per thousand gallons, in the size range of the Northfield Mountain Project and Millers River Basin Project, although the proposed California plant would produce water at 73¢ per thousand gallons at the plant site. Even at this reduced cost, however, desalinization is not competitive with present costs of developing natural surface and subsurface water supplies. For example, costs of water from this statement's proposed actions is about 13¢ per thousand gallons.

Aside from the economic costs involved with desalinization, the Office of Saline Water is also investigating the potential hazards to the environment which might occur. In considering placement for any type of desalting plant, environmental factors are as important as any other factor. Pure water is not the only product. A plant will produce extremely concentrated brine as an effluent, plus any waste products from the power source, such as soot, heat, smoke, toxic gasses, etc. So far as brine is concerned, this brine from distillation plants is of high temperature, higher chloride content and may contain concentrations of copper, all of which may prove injurious to the environment. Special design procedures would be required in the cases of estuaries or areas with restricted water interchange, as many life forms present might be adversely affected. Two land methods of disposal have been studied: (1) evaporation to dryness; and (2) deep-well injection. Evaporation is expensive, though this is highly dependent on land costs, presently quite costly in urban areas. Injection method costs are estimated at 25 to 70 cents per 1,000 gallons of brine. Such costs must be added to plant production and distribution costs to arrive at a true cost of water from this technology. At present, the Office of Saline Water is investigating other methods of brine disposal.

The future of desalting in the northeast is described as follows by the Office of Saline Water: [2]

"Existing desalting operations are characterized by several constraining features. Among the most important are high total annual costs, relative to conventional water sources; the need for proof of large-scale plant operation; and the problem of brine disposal. In the future,

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[1] Based on data contained in memorandum from Office of Saline Water to New England Regional Coordinator, U. S. Department of the Interior, 17 August 1972, based on 1972 price levels.

[2] Ibid.

as technology is further developed, several of the constraints will be lessened, and desalting may prove to be an attractive supplement to water supply in coastal and estuarine areas of the Northeast United States. Desalting processes may also serve future use as an aid in control of water quality." As a result, this report concludes that desalinization not be considered at this time as a viable alternative source of water in eastern Massachusetts for the short-range water supply problems. When and if the technology and efficiency of this process is refined so that it is economically and environmentally competitive with other methods of supplying water, its feasibility can be re-evaluated.

Importation

During the crisis years of the sixties' drought, many newspaper and periodical articles pondered the possibility of diverting water from extra-regional sources as a solution. One of the major basins often mentioned as a water supply source for the Northeast was the Saint Lawrence. As an alternative to developing local resources to meet future water needs, an investigation was made regarding the feasibility of diverting Saint Lawrence flow to meet future needs.

The Saint Lawrence River Basin is an impressive basin, both in its size and the annual runoff from its watershed. The drainage area is about 295,000 square miles at Ogdensburg, New York, which includes over 95,000 square miles of water surface area, most of which is in the five Great Lakes. Storage capacity within the lakes regulates the flow in the river to a large degree. The long term average discharge at Ogdensburg is about 240,000 cubic feet per second (155,000 mgd). From a review of these statistics, it is apparent that the basin, if developed, could meet the forecast supply demands for all of southeast New England.

Engineering studies were conducted to assess various methods and quantities of development from the basin. Cost estimates were prepared for projects which would service all of the Northeast through the year 2020. Construction costs for such facilities were estimated to be as high as 8.5 billion dollars, excluding any necessary water treatment costs. Water delivered from such an undertaking would cost substantially more than similar volumes made available from local resource potential.

In addition to the high cost of water, this alternative also has several other major disadvantages. First, the nature of the project would not allow stage development. Thus, large expenditures of funds would be required for distant long range needs. Second, since the basin is international, negotiations with Canada would have to be held and a treaty consummated prior to diversion. Assuming that Canada would be favorable to such negotiations, at best, any treaty would be in the distant future.

Based on the results of investigations conducted as part of this report, the importing of water to meet short-range water supply needs does not present a viable alternative for the southeastern New England Region.

Waste Water Reuse As A Municipal Supply

Waste water reuse, especially in industrial process application, has been economically successful in many sections of the country. The Bethlehem Steel Company in Baltimore, Maryland, currently uses about 120 mgd of treated municipal waste from Baltimore and uses this effluent in its quenching and cooling processes. The Dow Chemical Company uses treated sewage from the City of Midland, Michigan for use in its cooling water and fire protection system. In Amarillo, Texas, effluent from the municipal sewage treatment is used as cooling water and boiler make-up water for industries located in that city.

Other uses to which treated waste water has been applied include irrigation of both crop land and lawns, as a fresh water barrier against salt water intrusion, and in some cases as a source of supply for formation of recreation lakes and ponds.

Direct reuse of waste water effluent as a public water supply, however, has not been utilized to a large degree. Advanced waste treatment research and development programs at the Federal level are continuing and pilot plant studies such as the noted Lake Tahoe project are apparently meeting with success in producing a high quality effluent.

The current Drinking Water Standards do not apply to direct reuse of reclaimed water for drinking. In a series of recent articles, the Division of Water Supply Programs, Environmental Protection Agency, (formerly Public Health Service) have described a number of potential health programs which could occur with the use of renovated waste water. As stated in these articles, recent public repercussions from birth defects caused by thalidomine and from the side effects of other

new drugs, underscore the responsibility that health officials have in introducing or promoting the use of reclaimed waste water as a domestic source.

Health officials feel that many questions remain unanswered which must be fully investigated if renovated waste water is to be considered for drinking water purposes. Research considered vital was described in an article [1] prepared by the Director and Deputy Director, Division of Water Supply Programs. In their article, it was stated that "before development of intimate personal-contact uses of renovated waste waters, one needs to:

A. Initiate studies on viruses for:

1) Development of improved viral detection and enumeration methodology.

2) Exploration and definition of the basic properties of enteric viruses.

3) Provision of knowledge on transmission of viruses through the aquatic environment.

4) Definition of the impact of viral disease on man through associated epidemiological studies.

5) Development of technology for the positive removal and inactivation of viruses.

B. Investigate the potential problems from bacteria and other microorganisms in reclamation systems.

C. Identify and define the potential health effects of organic and other chemicals not removed by reclamation plants and subject to build-up, and develop techniques to identify and measure readily the concentrations of such chemicals.

D. Dispel the cloud that hangs over the whole subject of reliability for wastewater-treatment-plant operation. Reclamation plants for direct reuse must have fail-safe processes, back-up facilities, alternate means for disposal, continuous monitoring, and bioassay, and they must be operated in an atmosphere that demands reliability. State programs responsible for the operation of wastewater treatment plants

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[1] Lang, W. N. and Bell, F. A., "Health Factors and Reused Waters," Journal American Water Works Association, April 1972.

will require upgrading. Pilot and field-scale testing will be required for the validation of processes and practices prior to their widespread use.

E. Use common sense. Renovated wastewater should not be used for the ultimate personal use -- as a drinking-water supply -- until there is no other practical choice; and then, hopefully, the minimum research will have been completed and the use will be carefully operated and controlled. Meanwhile, in water-short areas, the renovation and reuse of wastewaters for industrial, limited irrigation, and other low human-contact purposes should be investigated and advanced.

The future of direct wastewater reuse, particularly in industrial applications, seems promising. Future water demand forecasts for industrial usage used in this report, in fact, anticipates greater recycling of water in the industrial sector. For example, industrial output projections of Standard Industrial Classification (SIC), category No. 28, Chemicals and Allied Products, indicate a 750% increase by 1990. Thus, if no recycling beyond that presently practiced were implemented, then anticipated water supply needs for this industry would increase over sevenfold. Future industrial supply estimates developed for this report, however, recognize many pressures are being exerted which should alter present industrial water use practices. In the SIC 28 category, described earlier, the possible changes in use practices were estimated to require a 370% increase in supply rather than the 750% which might be expected based on output forecasts.

Use of renovated waste water as a regular domestic supply, however, requires full results of proposed research. Until such research is completed, wastewater reuse as a municipal water supply is not a viable alternative to meet short-range supply needs.

Ground Water Resources

A study[1] of the ground water resources of Massachusetts was prepared for the Corps of Engineers by the United States Geological Survey. The study was based upon analysis and interpretation of available data and did not include any new exploratory work. The objectives of the study included an estimate of the area extent and sustained yield of principal aquifer reservoirs which might be used for supplementing municipal and industrial water supplies. The cost of producing the water was also estimated.

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[1] This investigation was conducted as part of the feasibility study of potential engineering alternatives in the study area.

A. Occurrence of Ground Water

A water bearing strata of rock material is called an aquifer. The principal aquifers underlying Massachusetts are of three types: 1) Stratified drift, layers of sand and gravel commonly interbedded with some silt and clay; 2) till, a non-stratified, poorly sorted mixture of clay, sand, gravel and boulders; 3) crystalline metamorphic and igneous bedrock. Till and bedrock aquifers yield small amounts of water, suitable only for domestic supplies. Only those aquifers occurring in stratified drift have the potential capacity to sustain large withdrawals of water.

Geologic reports and well logs were studied to determine the distribution and thickness of stratified drift deposits in Massachusetts. Deposits were found about everywhere in the state, but were most extensive in the valleys and outwash plains of the east and southeast area.

B. Hydrologic Parameters

In order to evaluate the aquifers as potential sources of water supply, their water transmitting and storage characteristics were studied. Permeability values, in gpd/sq. ft. were assigned to various lithologies such as gravel, sand and gravel and coarse - medium - fine sand on the basis of the relationship between grain size and permeability. The transmissibility, in gpd/ft., of a lithologic unit was then determined by multiplying the thickness of the unit by its permeability value. Coefficients of transmissibility and storage were also calculated from controlled pumping and drawdown tests at wells sunk in the aquifers.

The saturated thickness of the aquifers was mapped where data was available. The thickness was determined by subtracting the elevation of the base of the aquifer from the water table elevation. The saturated thickness of stratified drift, although not necessarily indicative of the presence of permeable zones, has been found by investigators to be a useable favorability guide for a general analysis of the ground water withdrawal potential. One further indicator of the water content of a ground water reservoir is the percentage of surface stream flow which is contributed by ground water. This portion of stream flow is termed base flow or ground water runoff. Analysis of past records indicates that average annual base flow of a given stream is approximately equal to Q-60 (stream flow equalled or exceeded 60% of the time) in a year of normal climate and equal to Q-70 in a dry year. The Q-70 flow is considered an index to the amount perennially available for consumptive use without depletion of storage.

The hydrologic criteria described above were applied to the principal aquifer reservoirs of Massachusetts. In this manner the capability of these reservoirs to serve as alternate sources of water supply could be evaluated. The rates of withdrawal from the aquifers were estimated by assuming the following conditions:

1) No recharge occurs for 200 days in dry years and all the water produced during this period is from ground water storage -- it is assumed that reservoirs capable of sustaining withdrawals under these conditions could continue producing forever;

2) The configurations of the reservoirs were idealized to form elongated rectangles;

3) A system of dewatering wells, 24" in diameter and spaced 2,000 feet apart for 2 mgd yields and 1,000 feet apart for 1 mgd yields, was hypothesized to aid in planning and cost estimates;

4) These wells were assumed to have no drawdown attributed to partial penetration, thinning of the reservoir, nor well losses;

5) Available drawdowns in the wells were limited to two thirds of the saturated thickness for water table conditions and to the top of the producing reservoir for artesian conditions;

6) Current withdrawals of ground water were included as a part of the estimated withdrawals.

The results were then tabulated by area and rate of withdrawal in mgd/sq. mile and total withdrawal in mgd.

C. Conclusions

The survey of ground water resources indicated that the aquifers in Plymouth County and parts of Cape Cod have the capacity to sustain long term, large magnitude withdrawals. The water demand on Cape Cod is increasing at a fast rate; therefore, this area is not considered in this report. The Plymouth County area studied comprises 300 square miles and its estimated safe yield is 300 mgd. This estimated rate exceeds the required quantity established as a goal of this study. Thus, it was concluded that the Plymouth County area could offer a viable alternative source of water supply for eastern Massachusetts.

Cost estimates for the necessary resource development were then prepared. Major development items included in these estimates were land

acquisition, cost of ground water well development, water treatment facilities, pumping installations and connecting aqueduct system to the metropolitan service area. The estimated construction cost for the ground water development per million gallons per day (mgd) capacity is about 1.2 million dollars. Costs for the Millers River Basin and Northfield Mountain Projects on the other hand are estimated to be about $540,000 per mgd capacity. Annual costs of ground water development which include interest and amortization; maintenance, repair and operating cost; and major replacement costs are estimated to require charges of about 25¢ per 1,000 gallons produced. Annual costs for the Millers River Basin and Northfield Mountain Projects would require about 13¢ per 1,000 gallons produced.

In addition to the economic costs associated with development of the ground water alternative, there are also potentially significant environmental and socio-economic impacts. For example, land taking activities associated with sanitary protection of the various wells may be substantial. Preliminary estimates of necessary land acquisition for the wellfield development indicate 2,000 to 3,000 acres of land would be necessary. This compares quite unfavorably with the 80 acres estimated to be required for the Millers River Basin and Northfield Mountain Projects.

Connecting pipelines between wells in the wellfield and transmission facilities to point of use would require a large amount of surface construction. Such extensive surface construction would have an impact on the environment in the vicinity of the wellfield and transmission facilities. Since portions of the aqueduct systems would pass through heavily urbanized areas, disruption would be expected to be extensive.

Since all water developed from the wellfield would have to be pumped to the consumer, this alternative would utilize large amounts of electricity. Thus, depending on the method used to provide this power, impacts on the environment may be expected. The Millers River Basin Project would utilize gravity feed and Northfield off-peak power; therefore, no additional potential environmental damage would accrue because of power requirements.

On the basis, then, of cost comparisons and potential socio-economic impacts, use of ground water does not appear to offer an attractive alternative to the proposed project.

Dual Water Supply Systems

An alternative which has been receiving attention of late has been the use of dual water supply systems. In these systems, a hierarchy of

water supply would be established whereby higher quality supplies could be used to furnish a potable source for drinking, cooking, dishwashing, cleaning, bathing and laundering. All other uses could be furnished by a second supply of lesser quality.

Two general methods have been suggested for such a dual system. The first is the possibility of recycling at the point of usage. Under this scheme, drinking, washing and bathing water would undergo treatment and then be further utilized as toilet flush water and outdoor uses. It is estimated that such a system could reduce domestic water use by as much as 50%.

Various systems for in-house reuse or for outdoor usage have been proposed and some are being marketed on a small scale.

Advantages to this system beyond potable water consumption reduction is the reduction in sewage water volume, sewer pipe and pumping requirements. Capital cost outlay for such a system based on limited cost data would be over twice as expensive as water delivered from this report's recommended project. Other disadvantages to this alternative lie with its limited application and accompanying operational experience, potential problems of odor and other aesthetic considerations. Health officials, in general, have not expressed their acceptance or rejection of such systems. However, their general apprehension on introducing less than potable water into the home environment could also reasonably be expected with regard to any system of this nature.

The second method which has been suggested for delivering higher and lower quality water for various uses would require a second distribution system. This second distribution system would carry river water or even sea water to supplement the high quality primary supply source.

Two methods of providing the second (lower quality) distribution system could be employed. The first would involve installation of the entire system immediately. The second, and more practical, method would be on an incremental approach wherein secondary systems are installed in new or replacement buildings above a certain size. The second approach was evaluated in this report. With this approach, water consumption is only reduced at a given time by the building construction that utilizes secondary systems.

To estimate costs for such a system, a report on the New York City area prepared as part of the NEWS Study was utilized. Based on the results of that investigation, preliminary capital cost estimates for

such a dual system would be about 6.5 million dollars per mgd saved. The Millers River Basin and Northfield Mountain Projects are estimated to cost about $540,000 per mgd. Therefore, it is quite apparent that use of a dual supply distribution system as an alternative would be an extremely expensive alternative.

In summary, then, use of dual water supply systems does not offer an alternative to the recommended project in this report. Of the two methods, the system which would recycle water at the point of usage holds the more promise for future application.

Other Diversion Sites

In addition to the Millers River Basin and Northfield Mountain proposals described in this statement, a number of other diversion possibilities were also evaluated. These other possible sources included diversions from: the mainstem Connecticut River at other than the Northfield Mountain location; a major tributary of the Connecticut River, the Deerfield River; the mainstem of the Merrimack River and the Sudbury River, a tributary of the Merrimack, formerly used by the MDC.

A. Other Connecticut River Basin Alternatives

Alternative methods of diversions from the Connecticut River Basin, such as the Deerfield River or another location on the Connecticut River, could provide an equivalent yield to that described in this statement. Development of either of these proposals, however, would be more expensive than either Millers River proposals or Northfield Mountain. Aside from economic costs, neither alternative appears to present any clear cut advantage from either an environmental or socio-economic standpoint. It appears then that development of these alternative sources would offer an opportunity for providing the necessary short-range water supply need. Their development, however, would be more expensive and would not offer any advantage over the projects described earlier.

B. Merrimack River Basin Alternatives

1) Merrimack River Mainstem

As an alternative to further diversions from the Connecticut River Basin, the potential of developing the Merrimack River mainstem was also investigated. Based on studies to date, use of the Merrimack River, to meet future needs, holds promise. Use of the river to meet immediate needs, however, does not appear to offer an alternative from either an economic or public health standpoint.

At present, the physical, chemical and bacteriological quality of the river is poor. For years the river has been subject to major discharges of municipal and industrial wastes. Because of these discharges, the Merrimack is often characterized as one of the ten most polluted rivers in the United States.

Even with the existing pollution load, the mainstem river is now used as a water supply for the Cities of Lowell and Lawrence. Water treatment facilities for both municipalities are conventional; however, taste and odor problems are experienced periodically at both locations.

Pollution abatement programs to implement secondary waste treatment facilities on point sources of pollution are under way by State and Federal agencies. Costs of these plants are estimated to be 235 million dollars. Upon completion of the abatement programs scheduled for 1976, the river will be improved as a water supply source.

A recent report by the Corps of Engineers,[1] in cooperation with the Environmental Protection Agency, investigated the feasibility of various alternatives for upgrading treatment processes beyond the planned implementation schedule. Cost estimates of the various alternatives ranged from 668 to 1108 million dollars. All of these plans would further enhance the quality of the river for use as a water supply source.

At present, the NEWS study is performing an Interim Report of Survey on those waste water treatment alternatives reported upon in the waste water feasibility report. The objective of this task is the evaluation of the various alternatives for their effectiveness in meeting the goals of the 1972 Water Quality Act. As a companion effort to the waste water element, investigations in survey detail on the river's potential for water supply development are also under way.

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[1] "The Merrimack: Designs for a Clean River," North Atlantic Division, Corps of Engineers, September 1971, Northeastern United States Water Supply Report.

In summary, at present, the Merrimack River Mainstem in Massachusetts is generally of poor quality. Alternative methods of treating the waste water discharges were assessed in a feasibility report by the NEWS Study. Followup survey detail investigations on alternative waste water treatment techniques and methods for developing water supply facilities are presently under way.

Based on studies to date, use of the Merrimack River to meet future water supply needs holds promise. Use of the River to meet immediate needs within the study area does not appear to offer an alternative to this report's recommended project from either an economic or public health standpoint.

2) Sudbury River

In 1846, the Cochituate Reservoir (previously Long Pond and presently Lake Cochituate) was acquired and developed to meet Boston's water needs through diversions from a subdivision of the Sudbury River watershed.

In 1872, the Sudbury River Act was passed which authorized the diversion of a portion of the Sudbury River waters to the Boston Water System. Subsequent to this Act, a series of reservoirs were construced by the Boston Water System and later by the Metropolitan Water District to develop the watershed. Construction on the last reservoir in the basin was completed in 1898 and a total of 75.2 square miles of drainage area was controlled.

In 1947, in response to the availability of supply from Quabbin Reservoir and the higher quality supply from this source, the Massachusetts Legislature transferred control of a number of the reservoirs to the Department of Conservation. The reservoirs transferred represented about 50 square miles of drainage area and were subsequently developed for recreational usage and their water supply use discontinued.

With its available supplies unable to meet its short range needs, the Metropolitan District Commission has reevaluated the potential which the full Sudbury system may have. Based on initial studies, it appears an additional 40 million gallons per day may be made available through flood skimming techniques.

The Sudbury Basin waters, however, have a number of water quality problems. Thus, to provide the potential yield, water treatment facilities would be necessary. Preliminary cost figures for needed facilities are estimated to be about 43 million dollars. In addition, transmission and pumping facilities may be necessary.

In order to fully estimate the potential and costs for redeveloping the Sudbury system, the MDC is preparing to initiate detailed investigations.

In summary, the "redevelopment" of the Sudbury River Basin could add an attractive increment to the available water supplies for this report's study area. Based on preliminary cost estimates, this increment is expected to cost about twice that of this statement's proposed actions. Yet to be determined as part of the MDC further study are the environmental and socio-economic advantages and shortcomings.

C. Conclusion

Alternative development of the Connecticut or Merrimack Rivers was evaluated as methods of meeting short range water supply needs forecast. Although either river basin offers opportunities, their development would be more expensive than the proposed project. In addition to economic considerations, use of the heavily polluted Merrimack River does not appear to offer an attractive alternative from a water quality standpoint for immediate supply needs.

The Sudbury system plan needs further study for a full assessment of its potential. If the Sudbury "redevelopment" plan were to be found attractive and constructed, however, it would be fully compatible with this statement's proposed actions.

Water Demand Control

The NEWS Study, cognizant of the narrow margin separating available yield and consumer demand, conducted studies on methods available to alleviate this critical water supply situation. Two general approaches to the problem were investigated: the first considered various methods of increasing the supply available to the system. The second approach described in this section was investigation of methods whereby demand could be curtailed.

A. Components of Demand

1) General

Water demand can be classified into four main categories. These are Domestic, Public, Commercial and Industrial. Nationally, of water withdrawn from public systems, 47 percent is delivered to domestic consumers; 13 percent to public uses; 18 percent to commercial; and 23 percent to industrial applications. A description of uses to which water is applied in the various categories is given in the following paragraphs.

2) Domestic

Domestic use, for purposes of this study, includes that water used by the consumer both within his home and that used by him for allied residential uses such as lawn sprinkling and car washing. In house uses of water include drinking, bathing, cooking, washing, and carrying away of wastes.

Total domestic water use in the United States amounts to approximately 73 gpcd. Few studies have been conducted regarding the composition of this demand; however, the U.S.G.S. reports domestic water in Akron, Ohio, was used in the following proportions:

Domestic Water Use

Carrying away of wastes	41%
Bathing	37%
Cooking and Washing	9%
Drinking	5%
Clothes Washing	4%
Lawn Sprinkling	3%
Car Washing	1%
Total	100%

3) Public

Public or municipal use on a national basis accounts for about 28 gpcd of the average 157 gpcd[1] supplied by public water utilities. Water used in this category is delivered to municipal facilities such as administration buildings, schools, hospitals, golf courses and other facilities used by the community at large. The water delivered in this category, of course, reacts to number and type of services provided. In Boston, for example, with a large number of hospitals and other institutions, it is reported 38 percent of total water use falls within this category. In Wellesley, a suburb of Boston, only 9 percent is recorded as public.

[1] gpcd = gallons per capita per day.

4) Commercial

A significant portion of all water delivered from public supply systems is used by commercial establishments. Nationally, it is estimated that 28 gpcd are used for this purpose. Within this category, is included department stores, restaurants, hotels, laundries and other service elements which serve the general public. No breakdown of water delivered to the commercial sector was available for the Boston Metropolitan area, but it is estimated 850,000 commuters travel daily to the City of Boston. Water supplied to these commuters for their needs while "temporary residents" cannot help but be a significant share of the water supplied to the City.

5) Industrial

Many industrial establishments obtain their water supply from public utilities. Of the average 157 gpcd recorded in the United States, 36 gpcd were used in industrial plants. The water withdrawn by these industries is used for three principal reasons: cooling water; boiler water or water used for the generation of steam and process water, which is water that comes in contact with the product being manufactured.

Available records on industrial use which record individual community usage are limited. On a state-wide basis, about 100 mgd or 13 percent of the publicly supplied water was drawn for industrial use in 1968. Within the MDC service area, a recent telephone survey conducted by the NEWS Study indicated about 8 percent of water withdrawn was used for industrial. On this basis, then, Massachusetts and the MDC service area are not heavily industrial water users if compared to the national percentage of 23 percent.

B. Methods of Controlling Demand

There are basically five methods which have been suggested as effective in controlling demands on water supplies. These are:

a) Changing from flat-rate to metered supply
b) Increasing the price of metered supply
c) Imposing of restrictions on water use
d) Utilization of water saving devices
e) Public water conservation education programs

Each of these methods outlined above are described in the following sections as they might apply to the demand forecasts prepared for this report.

1) Metering

The installation of meters which measure the amount of water used by a consumer have been shown to be effective in varying degrees in reducing demand for water supply. With metering, the customer is now charged for the quantity of water used, instead of being charged a flat rate for a period of time regardless of quantity used. Most of the studies conducted regarding the effects of metering indicate domestic in-house use is relatively in-elastic, but lawn sprinkling use and some industrial applications apparently are affected.

Use of metering then appears to present a good opportunity for conservation of a resource. In the Boston area, however, application of this technique to reduce demand is quite limited. Most municipalities in eastern Massachusetts already meter extensively. For example, the MDC system is presently 96 percent metered. Complete metering, therefore, would affect only 4 percent of service connections in this system and not, therefore, affect to any significance water supply demands forecast in this study.

2) Pricing Effects on a Metered Supply

a) General

A number of articles have appeared in recent years in water supply and water resource professional journals regarding the impact of price increases on water demand. All of these articles attempt to quantify the constraining influence which pricing may have upon demands. In these articles, a number of various pricing techniques have been suggested for administration of price hikes. These include general increases in price levels, seasonal pricing and increasing block rates for varying usage of water. Aside from the administrative technique employed, however, the objective of the articles is to define impact of price increases on demand. Generally, the authors, however, are forced to base conclusions on a generally incomplete and sporadic empirical data base. In the following paragraphs, a brief description of some of the major empirical studies is given. Following the study descriptions, an application of the empirical data findings to the eastern Massachusetts forecast demand is made for both the domestic and industrial water components. Finally, an attempt is made to correlate the results

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of the empirically derived data to the local water supply system experiences. Although the data presented later is applicable to general pricing increases, the conclusions are felt to apply regardless of administrative technique selected.

In 1957, H. F. Seidel and E. R. Baumann[1] prepared a statistical analysis of various water works data. In their analysis, the authors derived an elasticity coefficient of 1.0 for certain price levels and a lower, inelastic coefficient for lower price levels. The authors, however, noted that they remained skeptical that a rate adjustment has the prompt, proportional effect on water use which the elasticity coefficients suggest. They stated their review revealed that most rate adjustments are moderate enough and water use habits sufficiently stable to consign the rate factor to a "distinctly minor role as an influence on fluctuations in water use."

Linaweaver, Geyer and Wolff,[2] during the years 1961 - 1966, conducted studies to determine patterns of residential water use and factors influencing this use. The results were then used to determine design criteria for water supply systems. These studies were sponsored by the Technical Studies Program of the Federal Housing Administration, and were in cooperation with sixteen water utilities in various climatic regions. Both residential and apartment areas were studied. Climate, economic level of consumers, and pricing systems were considered and concluded as having in that order the major influences on water use.

The economic level of the consumer was considered to influence water use for several reasons. A consumer in a higher valued area is likely to have more water using appliances which increase the overall domestic use. A second reason advanced is that a higher-priced house usually has a larger lawn which will increase the sprinkling demand. Climate is a major factor influencing sprinkling use when there is a lack of precipitation, but it has little effect on in-house use.

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[1] Seidel, Harris F. and Baumann, E. Robert, "A Statistical Analysis of Water Works Data for 1955," Journal of the American Water Works Association, XLIX, No. 12 (December 1957).

[2] Linaweaver, F. P., Jr., Geyer, John C., and Wolff, Jerome B., A Study of Residential Water Use, Washington: Department of Housing and Urban Development Report TS-12, February 1967.

The cost of water also influences the demand. Based on their findings, the authors conclude that cost does not influence in-house water use to a great extent, but would decrease sprinkling use.

Howe and Linaweaver,[1] using the results of the Residential Water Use Study,[2] studied the effect of water pricing in residential areas. Included in the results of this study was the formation of two equations which, according to the study, described the relation of price on use.

The domestic in-house demand was considered best expressed by the following linear equation:

$$g = 206 + 3.47v - 1.30p$$

where g = gallons per day per dwelling unit
v = market value of dwelling unit in thousands of dollars
p = price per 1000 gallons in cents

By use of this equation, the authors concluded that the effect of price on demand and the price elasticity of domestic use could be determined.

Based on their use of this equation, Howe and Linaweaver next concluded that domestic in-house use represented a demand relatively inelastic with respect to pricing changes.

Effect on summer sprinkling demands by pricing was considered as described by the following equation:

$$g = 3657\, r^{0.309}\, p^{-0.93}$$

where $r = b(w - 0.6s)$

and p = price per 1000 gallons in cents
b = irrigable area in acres surrounding dwelling unit
w = average summer potential evapotranspiration in inches calculated by the Thornthwaite method about 10" in the eastern United States
s = summer precipitation in inches

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[1] Howe, Charles W. and Linaweaver, F. P. Jr., "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," Water Resources Research, III, No. 1 (1967).

[2] Linaweaver, F. P. Jr., Geyer, John C., and Wolff, Jerome B. A Study of Residential Water Use, Washington: Department of Housing and Urban Development, Report TS-12, February 1967.

From use of this equation, it was determined that the sprinkling demand was responsive to price change. The Howe and Linaweaver work indicated, then, that residential water demand is dependent on the price charged. Typical in-house demands exhibited a price elasticity of -0.23,[1] e.g., a 10% increase in price will reduce demand by 2.3%, while the price elasticity for sprinkling demands was 0.93. Sprinkling use is, therefore, more strongly affected by price change than domestic use. The authors felt that pricing could be used as an effective tool to decrease average day demands and increase revenue.

Because of the different industrial water use requirements and variations in plant process flexibility, a single elasticity coefficient for all industrial use is probably unattainable. Research in this field appears quite limited. One small scale study, however, has been undertaken within Massachusetts and the results of this study are described in the following paragraph.

Coefficients of elasticity for water demand response to pricing changes were studied by Stephen J. Turnovsky.[2] This study was primarily directed to the question of the response of individuals to an uncertain supply of water. From data collected from a sample of Massachusetts towns, the coefficient of elasticity derived for household use was around 0.3, and for industrial demand, about 0.5.

b) Application of Prior Study Conclusions to Eastern Massachusetts

As described in the previous paragraphs, both Howe-Linaweaver and Turnovsky have developed equations and price elasticity based on empirical data which suggest the influence which pricing may have on demand. In an attempt to determine the significance of these relationships to current water demand in eastern Massachusetts, a computer program using these relationships was developed for communities serviced by the MDC.

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[1] based on a house market value of $20,000 and cost of water at 40¢/1000 gallons.

[2] Turnovsky, Stephen J., "The Demand for Water: Some Empirical Evidence on Consumers Response to a Commodity Uncertain in Supply," Water Resources Research, V, No. 2 (April 1969).

Once the computer program had been developed, a series of hypothetical price increases were imposed on the existing municipal rate structures. The effect of these increases on both domestic and in-house use and lawn sprinkling requirements are shown in the following table:

TABLE 9

Effect of Hypothetical Water Supply Rate Increases on MDC Demand.

Theoretical Decrease

Price Increase ¢/1000 gals	Domestic Demand	Lawn Sprinkling Demand	Industrial[1] Demand	Total
5	4.3	1.2	1.4	6.9
10	8.6	2.1	2.7	13.4
15	13.0	2.9	4.1	20.0
20	17.3	3.5	5.4	26.2
30	21.6	4.1	8.3	34.0
40	25.9	4.6	10.7	41.2
50	34.5	5.3	13.7	53.5

c) Discussion

As illustrated in Table 19, price adjustments would appear to offer an alternative to development of supplemental water supplies. Theoretically, a price increase of 50¢ per 1,000 gallons could be expected to reduce domestic or in-house demands by about 34 mgd and a corresponding decrease in lawn sprinkling demand by about 5 mgd. Industrial water use demands are indicated to react by decreasing almost 14 mgd. The total theoretical decrease on the system then with such a price increase would be about 53 mgd.

On the basis of the theoretical equations then pricing would appear to be a valuable tool for conservation of the water resource. A number of questions, however, arise concerning the direct application of these forecast decreased demands to the water supply situation at hand.

[1] does not include partially serviced communities

First, the empirical data used in the derivation of the domestic use equations, although the most extensive to date is far from all inclusive. Data used was derived from 21 areas nationwide, which contained about 5000 dwelling units. None of the test areas were located within Southeastern New England, although data available from the Middle Atlantic States was used.

In the analysis of industrial water demand reaction data utilized was quite limited, and other research in this area is almost non-existent. Development of any hard policy conclusions based on such sketchy information is, therefore, uncertain at best.

Second, the derivation of the empirical equations for domestic use was based on a "static" view of cost versus use. That is, the data employed was not an observation of a group of communities actual reaction to pricing changes. Rather the equations were developed by using a number of communities, which for a given point in time, had different water use with their individual rate structures. For example, Community A in 1970 used 100 gpcd at a cost of 20¢ per thousand gallons; Community B in the same year recorded an average use of 50 gpcd at a cost of 40¢ per thousand gallons. Based on the approach used by Howe and Linaweaver, the expected decrease in use from Community A with a price increase to 40¢/1000 gallons would be 50 gpcd. Whether the use of such a "static" scenerio to predict dynamic conditions is valid is unknown.

That the equations may not indeed reflect the dynamic situation which would occur with a price increase is particularly suspect with actual operating experience in the Boston Region. For example, in the Boston Region, the MDC increased wholesale prices for its water from $40 to $80 per million gallons in 1954, and $80 to the current $120 per million gallons in 1962. Neither of these price increases was accompanied by a decrease in per capita demand on the system, in fact, demand increased on the system.

To further evaluate the dynamic impact of pricing in an actual operating experience, a survey was made of a privately owned water company which recently applied a 24¢ per 1000 gallons to its water rates. This rate increase raised the cost of water to the consumer from $1.00 to $1.24 per 1000 gallons. The two communities serviced by the company are principally residential, thus the rate increase based on the empirical equation should be expected to result in a demand decrease or, in any event, a decrease in the rate of increase. The company reports,

however, that instead of experiencing a decrease in per capita usage, it experienced a 5 gpcd increase, an increase in excess of that reported in years prior to the price increase.

Based on the actual operating experiences of these utilities within Metropolitan Boston, it appears that any arbitrary adoption of the empirical equation as a forecast tool with respect to water demand carries a large degree of uncertainty.

Third, all of the studies upon which the pricing - demand relationship was developed have been basically economic studies. No attempts have been made to evaluate or quantify cost to the consumers from either environmental quality or social considerations. Nothing systematic is known about such losses, in spite of the widespread occurrence of drought and shortage in recent years.

Both the social and environmental costs of reducing water demand may outweigh the gains derived from institution of such a policy. Whether, in fact, the costs would outweigh the benefits is unfortunately unknown.

In summary, use of increased water supply prices as a method to conserve a resource may have merit. Yet to be determined, however, are data to support the theoretical impact such increases would have upon the demand within New England. Also unknown with this approach are the social and enviromental costs which would be borne by the consumer. It appears then that much work remains to be done on this approach, such that it can be evaluated as a viable alternative to increased supply.

3) Imposing of Restrictions on Water Use

Historically, water utilities have used water use restrictions as a "safety factor" against depletion of supply during a drought. In general, however, most water utilities attempt to avoid restrictions whenever practical. Public reaction to such restrictions, however, is almost always unfavorable, and many examples of such public disapproval can be found in newspaper clippings during the recent sixties' drought.

Imposition of restrictions on water use could not fail to interrupt the existing and planned life styles of communities serviced by a water supply system. As described in the appendix on socio-economic impacts, restrictions on water use, depending on its degree, would

have far reaching social and economic costs. On the basis of costs which would be incurred with a restriction policy, it does not appear to offer a viable alternative.

4) Utilization of Water Saving Devices In-House

Much of the recent increase in municipal water supply by individual consumers has been attributed to the adoption of multiple toilet facilities; water using devices such as automatic clothes and dish washers; and shower installations. Variation in water use between brand names differ markedly. For example, automatic home washers for an 8 pound load require from 32 to 59 gallons per load, while toilets vary from 3.2 to 8 gallons per usage. Information on the impact of domestic water saving appliances on in-house use is limited and variable in quality.

An article[1] presented last year in the American Water Works Association demonstrated possible water savings which could be brought about by adoption of presently available appliances for toilet, clothes washing and shower use. In this article, the authors sought to determine whether the residential consumer would financially benefit by adopting the most up-to-date water using appliances. Varying replacement strategies as a function of costs were assumed. Based on their findings, the authors conclude that there doesn't appear to be current financial incentives for adoption of water saving appliances. They do note, however, that conversely economic costs to consumers from utilizing water saving appliances do not seem great. Presumably, their conclusion refers to replacement costs when currently used appliances wear out. The authors suggest that complete replacement of appliances with water saving models might reduce domestic water use by 32 percent.

A second study[2] of water conservation measures for the Office of Water Resources, U. S. Department of the Interior, also contains some information on water saving devices. In this study, it was noted that

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[1] Howe, Charles W. and Vaugham, William J., "In-House Water Savings," Journal of the American Water Works Association, Vol. 64, No. 2, (February 1972).

[2] Hittman Associates, Inc., "Main C. Computerized Methodology for Evaluation of Municipal Water Conservation Research Programs," No. HIT-409, Columbia, Maryland, August 1969.

increasing use of water by automatic dish and clothes washers over the years has been occasioned by a rise in required performance standards. Thus, customer desires are reflected in the increased water use.

A third study[1] recently completed for the Washington Suburban Sanitary Commission provides a brief review on the effectiveness of water saving measures and the relationship of their use to rate-making policy formulation. In this report, the authors state, "A major deficiency in the data reported by all investigators to date is that it refers to isolated uses of specific appliances and fixtures, but does not reflect actual use conditions. For example, reducing the water requirement of a toilet from 5 to 3 gallons per flush may be assumed to produce a corresponding decrease in water demand for that particular use. If the modification required to accomplish this reduction, however, interferes with the flushing action of the toilet, then the result may be an increased number of flushes which partially or completely nullifies the expected savings."

In reference to the suggestion that 32 percent of the domestic water use could be saved by adoption of water saving devices, the authors state, "Such a result implies, of course, no reduction in the actual or perceived efficiency of operation of any of the appliances or futures. In the latter instance, the net reduction in water use is more difficult to predict; however, it should be somewhat less than 32 percent."

Statements made at a number of progress meetings suggested that use of incentives such as subsidies or tax concessions and revision of plumbing codes to require water saving devices would result in substantial water savings.

In general, however, the same questions which burden analysis of price as a demand moderation measure also apply to use of water saving devices. Regardless of managerial technique used to implement use of such devices (i.e., subsidy, tax concessions, etc.) the question still remains as to the effectiveness and impacts on water use which may occur. Research conducted to date has been limited and supporting evidence to prove or disprove possible water savings is lacking. In addition, socio-economic impacts which might occur with a general requirement that older appliances be replaced with the water saving

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[1] Boland, John J., Hanke, Steve H., and Church, Richard L., An Assessment of Rate-Making Policy Alternatives for the Washington Suburban Commission, Prepared for the Washington Suburban Sanitary Commission, September 1972.

models has not been addressed at all. Environmental impacts generated as a spinoff of producing the new replacement models may also be significant and must be included in any analysis.

In summary, adoption of water saving devices as a method of conserving water supply may have merit in the long run. At present, however, supporting data to measure the impacts of either requiring new housing units or replacement by older housing with water saving appliances is not available. Without this data, evaluation of potential savings as an alternative course of action to the recommended project cannot be documented.

5) Public Water Conservation Education Programs

Historically, the water supply industry has not advocated wide scale public water conservation, except in communities where supply or distribution systems were inadequate to meet demand. Recently, however, increased awareness of the need to protect and enhance the environment has required a review of this earlier policy.

At present, two[1] major metropolitan supply systems have adopted a water conservation policy during a time of water surplus. In the past year both utilities have promoted expanded voluntary customer water conservation through a public education program.

Bill inserts and information handbooks on water saving measures have been distributed widely. In addition, speeches to individuals, schools and clubs have been employed to inform the public of why the water resource should be used properly and what they can do to help conserve water. Results of the education programs are now being evaluated for their effectiveness.

The Washington utility which has the longest experience record reports results have been encouraging to date; however, major reductions in per capita usage have not been observed.

In addition to voluntary conservation measures, the two utilities are also considering the use of regulatory powers to conserve water. Regulatory measures under consideration include, for example, price increases, utilization of water saving household appliances and

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[1] Washington Suburban Sanitary Commission and East Bay Municipal Utility District. Note: both utilities service populations of about 1.1 million each.

restriction of lawn sizes. All such measures, however, are being carefully evaluated by the utilities because of the many questions, described in earlier sections, which surround use of such devices.

In summary, adoption of public water conservation programs as a management tool has received attention of late. Results on water use modification of the voluntary conservation programs now under way are limited. However, based on the Washington area experience, no major decrease in per capita usage has been observed.

Re-Examination of the Swift and Ware Rivers Downstream Release Schedules

At the time diversions were contemplated from the Connecticut River Basin, via the Swift and Ware Rivers, Massachusetts applied to the Secretary of War for authority to make the proposed diversions. After hearing arguments pro and con from Massachusetts and Connecticut, the Secretary permitted diversion of the flood waters of the Ware in excess of 85 million gallons per day between 15 October and 15 June and prohibited the taking of any water except during that period.

With regard to the Swift River, the Secretary permitted diversion of all waters of the Swift except enough to maintain a flow therein of 20 million gallons per day (mgd) or 31 cubic feet per second (cfs). The Secretary did require that during the period from 1 June to 30 November there shall be released from the impounding dam 71 mgd (110 cfs) whenever the flow of the Connecticut River at Sunderland, Massachusetts is 4650 cfs and 45 mgd (70 cfs), when the flow is more than 4650 and less than 4900 cfs.

These findings of the Secretary of War regarding operational schedules for the diversions were later made a part of the Supreme Court Decision, dated March 1931, in the suit between Connecticut and Massachusetts. Since the date of that decision, diversions from the Swift and Ware Rivers have been accomplished under the Secretary of War findings.

During the progress of the NEWS Study, an interested citizens' group suggested the setting aside of the Swift River diversion limitations with the objective of retaining presently scheduled releases within Quabbin Reservoir. The citizen group further suggested any diminution of flow in the Connecticut River could be made up by releases from existing

Corps of Engineers' flood control reservoirs. In keeping with this suggestion, an examination was made of the potential which such re-scheduling might have on the short-range supply problems.

The drainage area of the Swift River controlled by the Quabbin Reservoir totals 186 square miles. The long-term average annual runoff from the watershed is 187 mgd (289 cfs) of which 32 mgd (50 cfs) has been released downstream in compliance with the existing downstream release schedule.

Thus, the maximum addition to the existing water supply system which could be achieved through re-scheduling would be 32 mgd (50 cfs). To provide this increment, however, all downstream releases would have to be terminated. Such a complete cessation of downstream releases with the subsequent "drying up" of the river reach downstream is, of course, impracticable. The question then raised is what level is practicable. A recent study[1] completed for the entire Connecticut River Basin recommends an instantaneous discharge rate, from power reservoirs on the Connecticut River of 0.20 cubic feet per second per square mile of upstream watershed. An application of this criteria to Quabbin Reservoir, for example, would result in a downstream release requirement of 24 mgd (37 cfs). Adoption, then, of such a modified operational schedule could result in an additional 8 mgd being made available. This increment of yield, however, would not begin to meet the short-range needs of this report's study area which are estimated to total an additional 141 mgd. In short, then, a re-examination of downstream release schedules with the objective of conserving such releases for water supply has merit. However, based on the requirement of maintaining a viable river environment downstream from Quabbin, the opportunity for reducing downstream releases does not offer an alternative.

The spring runoff which occurred in 1972 was of longer duration and of greater magnitude than is usually experienced. As a result, diversions from the Ware River, in compliance with the operation schedule described earlier, were forced to cease even though flows in excess of 85 mgd were still occurring. This event triggered a suggestion to the NEWS Study that if the 15 June to 15 October no diversion constraint were lifted, large additional supplies of water could be made available to Quabbin.

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[1] Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin, Connecticut River Basin Coordinating Committee, June 1970.

A computer test was made to determine the impact of the 15 June to 15 October constraint. The results of the computer simulation indicated that only an additional 2.6 mgd might be made available if the 4 month no diversion period currently in effect was terminated.

In the Ware River, as in the case of the Swift River, a re-examination of downstream release schedules may have merit. However, terminating the 15 June to 15 October diversion period constraint does not offer an alternative.

6. The Relationship Between Short-Term Uses of Man's Environment and the Maintenance of Long-Term Productivity

Simply stated, the diversion of water envisioned by these projects would constitute a long-term use of some of the donor areas resources for the long-term productivity of the receiver area. The planning process, which included extensive engineering studies and an assessment of the biological and environmental data accumulated during the study period, did not uncover any irreversible actions or drastic effects on the area environment. It did, however, bring forth findings discussed elsewhere in this report which represent "trade offs" which are the alternates of two or more courses of possible action. Even by attempting to clearly delineate these points, it was found that words which have acquired a specific connotation in relation to the study become a major problem in interpretation. The phrase, "flood skimming" is a case in point. In its original sense, it was used to denote a course of action to divert water in the spring during the high flow period. It was as it has turned out, an unfortunate choice of descriptive words because it has led to an erroneous opinion that the total volume of the "flood waters" will be "skimmed." In actuality, for example, the Connecticut River under the proposals discussed in this draft would lose 2-3/8" of elevation at Montague City at the maximum diversion rate. This small loss in elevation would be unnoticeable to the casual observer.

The project as proposed would adversely effect the environment during the construction aspects. This would only be a temporary condition as the areas affected would be restored after the construction phase is completed. Regarding tunnel construction, the material to be excavated is believed to be clean and suitable for later use. These uses of our environment will serve to achieve the goal of this project, namely, an adequate supply of good quality water. The alternatives previously described, if and when implemented, would also serve this purpose, but would not prevent Quabbin Reservoir from deteriorating as Quabbin is used while these plans are implemented.

It is important that the quality of Quabbin Reservoir must be preserved not only for water supply but also for the diversified fish and wildlife resources which are found within. This we can all agree on, but the issue here is what is the best way. Is it by restricting the use of water, or by adding more water to Quabbin, or even some combination of the two? Conservation methods, if properly used and understood by the public and industry would certainly conserve water and prolong the lifetime of Quabbin. But would it be enough so that other sources of water could be developed? Diversion from the Connecticut River would

prevent Quabbin from going dry in the next two decades, but would it degrade the present water quality or seriously disrupt the present equilibrium at Quabbin? These are the questions that have to be dealt with.

Studies to date have indicated that no serious problem would be created at Quabbin by the proposed diversions. With further pollution abatement programs along the Connecticut River and its tributaries, the water quality of the river will be further enhanced, thus the risk of degradation of Quabbin Reservoir due to diversions would be less. These studies have also shown that the estuary and areas downstream of the diversion sites would not suffer any great effects. If the diversions become a reality, additional studies will add to our knowledge and enable us to use our resources with the least amount of damage to our environment.

7. Irretrievable or Irreversible Commitment of Resources

All of the actions considered during the course of these studies would commit time and money. Further, structural measures would involve the commitment of materials to build the projects and would require the pre-empting of specific sites for other uses. Creation of weirs, tunnels, aqueducts and other fixed structures will commit these sites to long-term changes in present land use patterns. The precise extent of this commitment is unknown at this planning stage, but the impact can be minimized in the detailed project planning stage and by such tools as local land use and zoning. Nevertheless, although minor, it is a commitment to be recognized at this time.

Alterations to the landscape may also have an impact on those species of birds which pass through on their migration or remain to nest and raise their young. No known Endangered Species of birds or animals listed by the Fish and Wildlife Service utilize the proposed project lands. The amount of nesting habitat for migratory species will remain essentially the same in the region as it is at present.

Diversion of waters from the Connecticut River into Quabbin Reservoir represents an irreversible commitment. Once a diversion is made, there is no way to separate out the water diverted from the Connecticut River from the water already present at Quabbin. The same is true for diversions from the other proposed river systems. At any time, however, the diversions could be halted for health or environmental reasons. Thus, the decision to divert or not is reversible.

8. Coordination With Other Agencies

In November 1972, copies of the preliminary draft environmental statement were furnished to over 250 Federal, State, local and private agencies, organizations and citizens. With the end of the review period, approximately 40 agencies had responded, raising some 200 questions. Much of the text has been revised in response to these questions.

Many different respondees raised similar points. To avoid any unnecessary redundency, this section has been divided into two parts. The first part deals with the more general issues, indicating where in the text changes were made in response to the various questions. The second part is the standard comment and response which deals with more specific questions.

A. General

1) Alternatives

The comments offered generally stated that the alternatives to the proposed diversions were not fully considered. As a result, the section on alternatives, section 5, has been expanded to include a greater discussion of the costs, impacts and rationale involved in each of the alternatives.

a) Desalinization

Many reviewers felt that desalinization could provide a long-term solution to the water crisis as well as an alternate source of water in the event Quabbin Reservoir or any other sources become contaminated for a period of time. This is true to some extent. Desalinization is a long term solution since once a plant is built it would continually be a source of good quality water. Nevertheless, desalinization would not satisfy the need for water in the near future (1976 - 1985 time frame). In addition, this alternative would create environmental problems (disposal of high temperature brine, large energy requirements) which the present technology cannot resolve. Desalinization could provide a water supply for the 1990 - 2020 time frame and will be given more consideration as the technology is further developed.

b) Waste-Water Reuse

Waste-water reuse is an alternative recommended by several reviewers as a way of conserving our dwindling water resources. The major

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concern here is for the public health and safety. Even after treatment, microchemical pollutants remain, some of which are toxic. Before being released to the general public, any treated waste-water should be thoroughly tested. The problem here is that the bacteriological tests take 24 - 48 hours before the results are ready while the tests for toxic chemicals take a few days. This means that the consumers could use the water before it is found safe unless the water could be stored at the treatment plant until all the studies are completed. Additional studies and monitoring are needed to insure that this method will be a safe source of water for domestic use.

To get an idea of the magnitude of the problem, in the USSR, health authorities have listed some 300 chemical parameters as drinking water standards with others under study, many of which were established on organoleptic grounds. In this country, only 20 parameters are used with nine serving as the absolute grounds for acceptance or rejection of a water supply.

2) Environmental Impacts

a) Downstream Effects on Connecticut River Ecology

One area of great concern to the reviewers was downstream effects on the salt - fresh water boundary at the estuary and on marine life dependent on this delicate balance. Section 3 - A1 discusses the impact of removing a part of the flood waters on the ecology of the estuary while the next section 3 - A2 deals with the mainstem of the Connecticut River. Both sections have been expanded to fully consider all aspects.

b) Control Flows and Downstream Water Supply

A concern was expressed by several people that the proposed diversions would remove water from western to eastern Massachusetts, thus creating the same and additional water shortage problems in the donor areas as predicted for the Boston area. This is not the case.

Throughout the valley, a large number of studies on future water supply needs and sources have been conducted. These studies include investigations by Federal and regional planning agencies as well as municipal level reports. In no case has any investigation indicated that the diversions under consideration would affect water supply plans by other potential users within the valley.

In 1960, community water supply requirements downstream from the proposed diversion intakes totaled about 159 million gallons per day (mgd). The recently completed Connecticut River[1] Comprehensive Study estimated this total to increase to about 575 mgd by the year 2020. Privately supplied industrial water requirements totaled about 253 mgd in 1960 and is estimated to increase to about 312 mgd by 2020 for areas downstream of the diversion intakes.

The 17,000 cfs control flow used in the diversion study on the other hand is equivalent to about 11,000 mgd in the river at Montague City and about 12,700 mgd at Thompsonville, Connecticut. Thus, the minimum river flow which must be in the river before any diversion would be allowed is far in excess of reported basin water supply needs.

The situation between those communities which would receive the diverted water and the municipalities in the valley is totally distinct. On the one hand, receiver communities are faced with distinct possibilities of water shortages. The valley communities, however, would not face water shortages because of the diversions. The adopted study minimum control flow requires a minimum flow of 11,000 mgd at Montague City, Massachusetts, before diversions would take place. This flow is thus available for valley needs. In order to place some measure on this available quantity of flow, it is again noted that in 1960, total municipal supply used in the valley downstream from the diversion projects was 159 mgd or about one-seventieth of the control total.

c) Biota and Non-Sport Fish in Connecticut River

This section discussed the presence of species considered to be objects of angling efforts for two reasons. One, information on fish populations readily available to the Corps is generally required by Fish and Game Departments whose interest, understandably, is with those populations of interest to the angler. Fishing information gathered by Massachusetts Fish and Game which was used in the preparation for Exhibit "R" required by the Federal Power Commission provided our base information. Note that in the Massachusetts Fish and Game comments attached, additional studies by them indicate that catfish are not important in this stretch of the river, and they do have some indication of possible walleyed pike spawning below Vernon Dam. Our second reason on citing

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[1] Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin, June 1970.

sport fish is that, in general, they represent the top of the piscivorous food chain. Being so, their presence in the river indicates the biota below them in the chain is present in sufficient numbers to provide the base needed for their survival and to maintain a population. All of the fish cited can be classified as species which are successful in riverine situations if their individual requirements for temperature, dissolved oxygen, etc., can be met by the system. This is useful know as a riverine system is very unsteady when compared to the more relative stable conditions found in lakes and ponds. Temperature changes, rapid fluctuations in flows, seasonal and even daily changes are much more pronounced in a river. For a species of fish to survive in such an environment, they must be much more adaptable than those types generally restricted to ponds and lakes.

The following data has been taken from the Exhibit "W" prepared by Western Massachusetts Electric Company for their application to relicense their Turners Falls Project. This information, we believe, will assist in answering some of the questions raised about the presence of biota in the river other than the sport fisheries discussed in the draft.

Nest builders, such as the black basses and sunfishes are presently coping with the fluctuating water level in the pool and natural reproduction does not appear to be a factor limiting their abundance anywhere in the pool. The Project's operation in conjunction with the Northfield Project will increase the fluctuation in water level; but due to the configuration of the basin, the percentage of bottom alternatively covered and exposed will not be significantly changed. Before the operation of the Northfield Project, normal full pool had a surface area of 2,000 acres and a normal low pool of 1770 acres -- a difference of 230 acres. With Turners Falls Project and the Northfield Project operating at normal maximum, the full pool will have 2,110 surface acres and low pool will have 1,770 acres -- a difference of 340 acres. The percentage of bottom exposed in relation to surface area is not greatly different -- 12% compared to 16%. Therefore, the effect on habitat for nest builders and other fishes should not be deleterious.

In order to have the perspective of efforts made elsewhere to predict the effects of a pumped hydro plant on fisheries, it is useful to refer to a study [1] initiated by the Delaware River Basin Commission, which

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[1] Baren, C. F. - Limnological effects of simulated pumped-storage operation at Yards Creek 1971, Delaware River Basin Commission Report.

in 1967, 1968, and 1969 attempted to duplicate the effects of a pumped storage project on an aquatic biota through the use of test ponds. Test fish species were rock bass, blue-gill, pumpkinseed, large-mouth bass, walleye and yellow perch. The maximum diurnal draw-down tested was 3.5 feet.

Within the limitations of such simulations, the findings were reassuring regarding potential adverse effect. Nest builders produced somewhat fewer nests in the fluctuating water level ponds than in the control pond, but reproduction appeared quite adequate. Yellow perch and walleye also spawned successfully. While the control pond in these experiments produced more juveniles in one year, in that same year, two of the fluctuating level ponds produced more total weight of fish. To quote from the report:

Conclusions

1. It was concluded that fish adapted to the uniform regime of water level fluctuations and were successful in spawning and hatching eggs. No unusual problems were apparent in the early development and growth of fish. The slight decrease in recruitment of fish observed in this study could be beneficial in most natural situations.

2. It was further concluded that the measurable effects observed in plankton and macroinvertebrate productivity, plant colonization, relative condition factor of fish, and physical and chemical properties of the test ponds had no marked effect on the fish populations therein.

Growth rate studies in the Turners Falls Pond show that all species, with the exception of smallmouth bass, grow fairly rapidly by Massachusetts standards. Smallmouth growth was about at the state average in 1964 but has decreased since. Scales from the 1964 Dingell-Johnson project were reread by the present study to provide consistency in this method of age determination.

To determine whether localized environmental factors might affect growth, comparisons were made between walleye, smallmouth and yellow perch taken at the various fish collection stations. Walleye and yellow perch show no apparent difference but smallmouth bass show slightly slower growth rate at the stations in the upper pool area.

Stomach analyses were made on walleye, smallmouth bass, yellow perch and largemouth bass.

In general, the walleye is almost entirely piscivarous in feeding habits; the smallmouth diet is about 80 percent fish and during the summer a large proportion of the remainder is made up of various terrestrial insects; yellow perch utilize fish for about 95 percent of their diet with a strong preference for spottail shiner and their own young; the largemouth diet is about 97 percent fish with rock bass, bullhead and yellow perch being important items.

The picture that emerges from these food habit studies is of a game fish population that is supported primarily by a diet of other fish and with relatively little direct reliance on the benthic population. This would seem a normal situation in a run-of-the-river pond with a routine regime of fluctuating water level and an abundance and variety of forage fishes able to efficiently utilize the benthos, macroinvertebrates and plankton.

d) Construction Impacts

A number of agencies and individuals asked for more information on the impacts created by tunnel construction and disposal of the excavated material. These impacts are fully discussed in section 3-B7, Possible Environmental Impacts Caused by Construction.

e) Socio-Economic Trade-Offs

The analysis of socio-economic impacts was deemed as inadequate by several reviewers. The general feeling was that more consideration of these impacts in western Massachusetts and Connecticut was necessary. Accordingly, section 3-B9, Socio-Economic Impacts of the Projects on the Connecticut River Valley, has been added to rectify this situation.

f) Future Actions

The projects described in the impact statement are the only actions known to be receiving consideration. To meet any future needs, a number of other actions such as the development of the Merrimack River and conservation measures are also being considered. Therefore, the conclusion by many reviewers that future actions on the Connecticut River are inevitable is incorrect. When and if these other actions are developed further, environmental impact statements will be prepared to allow for input from all interested parties. Also, in the case of future diversions whether from the Connecticut River Basin or

the Merrimack River Basin, before any action can take place enabling legislation by the states involved would be necessary. Prior to the passage of such legislation, an opportunity would be available for additional input by the public.

g) Definition of Wetlands

Because of the diversity of opinions in the correspondence received on exactly what constitutes a wetland, we have included the definition of the Bureau of Sport Fisheries and Wildlife (see their letter), and a definition developed by the Massachusetts Wetlands Research Project, administered by the University of Massachusetts, is included on the following two pages.

A DEFINITION OF FRESHWATER WETLANDS[1]

Wetlands are those areas of land where water is so abundant that it is the major factor that dictates the nature of plant growth on the site. Relatively dry wetlands may have mature forests as the major vegetation, but the land surface is frequently flooded and the forests floor is covered with ferns and pocked with spring pools where few rooted plants survive. The most aquatic of the wetlands are the deep fresh marshes. These are shallow ponds where woody vegetation is sparse while water lilies and underwater plants are abundant.

Several systems have been devised to classify and name wetlands. The most broad and most widely used is that of the U. S. Fish and Wildlife Service (Martin et. al. 1953) which recognizes 20 wetland types. In the Northeast, and in Massachusetts, our study area, fresh meadows, shallow fresh marshes, deep fresh marshes, shrub swamps, wooded swamps and bogs are the common freshwater types. These are very broad categories and one portion of our research has developed a more detailed classification system better adapted to the Northeast (Golet, 1972).

A Proposed Definition

With the advent of legislation restricting alteration of freshwater wetlands it becomes important to construct a formal definition of wetlands to ease application of the laws. Rhode Island and Connecticut have taken this step. We have combined these acts and added from our own studies to produce the following definition, retaining the legal style characteristic of legislative acts:

Freshwater wetlands include, but are not limited to, wet meadows; marshes; swamps; bogs; areas where groundwater, flowing or standing surface water or ice provide a significant part of the supporting substrate for a plant community for a significant part of the year; emergent and submergent plant communities in inland waters; that portion of any bank which touches any inland waters; and land, including submerged land, which consists of any of the soil types designated as but not limited to, very poorly drained by the National Cooperative Soils Survey, as may be amended from time to time, of the Soil Conservation Service of the United States Department of Agriculture.

Wet Meadows are places where ground water shall be at the surface for a significant part of the growing season and near the surface throughout the year and/or where a vegetational community shall be made up of, but not limited to nor necessarily include, all of the following plants or groups of plants: rushes (Juncaceae), sedges (Cyperaceae), hydrophytic grasses (Graminae), cattails (Typhaceae), bur-reeds (Sparganiaceae), water-plantains (Alisma), Arums (Araceae), Iris (Iridaceae), Dock (Rumex), Smartweed (Polygonum), false loosestrife (Ludwigia), purple loosestrife (Lythrum), loosestrife (Lysimachia), blue vervain (Verbena), boneset (Eupatorium perfoliatum), Joe-Pye weed (Eupatorium dubium).

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[1] This is extracted from A Guide To Important Characteristics And Values Of Freshwater Wetlands In The Northeast, edited by Joseph S. Larson, and to be available from the University of Massachusetts Wetlands Research Project, Spring 1973.

Marshes are places where a vegetational community shall exist in standing or running water during the growing season and/or shall be made up of one or more, but not limited to nor necessarily including all, of the following plants or groups of plants: Hydrophytic grasses (Gramineae), sedges (Cyperaceae), rushes (Juncaceae), cattails (Typha), pickerelweeds (Pontederiaceae), water plantains (Alismataceae), bur-reeds (Sparganiaceae), pondweeds (Zosteraceae), frog-bits (Hydrocharitaceae), arums (Araceae), duckweeds (Lemnaceae), water lillies (Nymphaeceae), water milfoils (Haloragaceae), water-starworts (Callitrichaceae), horsetails (Equisetaceae), naiads (Nayadaceae), buckwheats (Polygonaceae), arrowgrasses (Juncaginaceae), bladderworts (Utricularia), pipeworts (Eriocaulon), sweet gale (Myrica gale), buttonbush (Cephalanthus occidentalis).

Swamps are places where ground water shall be near or at the surface of the ground for a significant part of the growing season or runoff water from surface drainage shall collect frequently and/or where a vegetational community shall be made up of, but not limited to nor necessarily include all of the following plants or groups of plants: red maple (Acer rubrum), elm (Ulmus americana), black spruce (Picea mariana), white cedar (Chamaecyparis thyoides), ashes (Fraxinus), poison sumac (Rhus vernix), larch (Larix laricina), spicebush (Lindera benzoin), alders (Alnus), skunk cabbage (Symplocarpus foetidus), hellebore (Veratrum viride), hemlock (Tsuga canadensis), sphagnums (Sphagnum), azaleas (Rhododendron), black alder (Ilex verticillata), white alder (Clethra alnifolia), march marigold (Caltha palustris), blueberries (Vaccinium), buttonbush (Cephalanthus occidentalis), willow (Salicaceae), water willow (Decodon verticillatus), tupelo (Nyssa sylvatica), laurels (Kalmia).

Bogs are places where standing or slowly running water shall be near or at the surface during a normal growing season and/or where a vegetational community shall have a significant portion of the ground or water surface covered with sphagnum moss (Sphagnum) and where the vegetational community shall be made up of a significant portion of one or more of, but not limited to nor necessarily include all of, the following plants or groups of plants: blueberries and cranberry (Vaccinium), leather-leaf (Chamaedaphne calyculata), pitcher plant (Sarracenia purpurea), sundews (Droseraceae), orchids (Orchidaceae), white cedar (Chamaecyparis thyoides), red maple (Acer rubrum), black spruce (Picea mariana), bog aster (Aster nemoralis), larch (Larix laricina), bog rosemary (Andromeda glaucophylla), azaleas (Rhododendron), laurels (Kalmia), sedges (Carex), bog cotton (Eriophorum).

B. Comment and Response:

The following Federal and State agencies offered no comments in their replies to the preliminary draft:

U.S. Department of Agriculture, Soil Conservation Service
- Connecticut
- Massachusetts
- New Hampshire
- Rhode Island
- Vermont

Department of Housing and Urban Development, Region I

U.S. Department of Transportation, Federal Highway Admin., Region One
- Connecticut
- Massachusetts
- New Hampshire

Federal Power Commission

Office of Economic Opportunity

Commonwealth of Massachusetts
- Metropolitan District Commission

State of New Hampshire
- State Clearinghouse
- Water Supply and Pollution Control Commission

State of Rhode Island and Providence Plantations
- Statewide Planning Program

Correspondence received from these agencies are included as part of this final statement. The major points of the agencies comments are summarized below:

U.S. Environmental Protection Agency

Comment: Turbidity entering Quabbin Reservoir should be kept low. Necessary monitoring should be defined and methods of controlling turbidity discussed.

Response: The importance of turbidity and its possible impact on Quabbin Reservoir was a consideration throughout the conduct of the study. To insure the acceptability of water delivered to Quabbin, the Northfield Mountain and Millers River Basin reports recommend the installation and maintenance of water quality monitoring stations. The location of these monitoring stations would be upstream of the diversion intakes and within Quabbin Reservoir itself. Both location, parameters to be tested and frequency of testing would be established by the Federal and State agencies who have responsibility in the safeguarding of public water supplies. Acceptance or rejection of water to be diverted during the life of the project would be determined by these responsible health agencies.

Comment: EPA agrees with Massachusetts Public Health directive that diverted water be chlorinated prior to entry into Quabbin Reservoir. Impact statement should include effectiveness of such water treatment and other treatment on diverted water.

Response: Water quality data collected as part of the NEWS reports indicates chlorination prior to entry of diverted flow to Quabbin Reservoir may be less effective than treatment applied to outflow water. Concurrence on this conclusion based on available data was made during the study by various Public Health Service engineers. Further water quality studies would be conducted during the Advanced Engineering and Design Phase of the projects. (The impact statement reviewed is for the planning phase of the projects). During the advanced engineering and design phase which precedes construction and operation of the project, the water quality data collected will reflect any improved or deteriorated upstream conditions. Utilizing this data as well as past background quality information, a determination can be made in consultation with responsible health officials as to the type of treatment required. If for example, chlorination is required based on existing river quality at that time, such facilities can be included in the design.

Comment: Pollution abatement plans for the Connecticut River are important in controlling the introduction of pathogens into the reservoir. The impact statement should indicate modifications that will be made if water quality is not found suitable for diversion in 1976.

Response: The NEWS study agrees that control of upstream waste discharges is necessary to protect water quality of the proposed diverted flow. The Environmental Protection Agency, in cooperation with the New Hampshire Water Supply and Pollution Control Agency and the Vermont Division of Water Supply and Pollution Control has established an implementation schedule for abatement of all point sources of pollution upstream from the Connecticut River intake. This implementation schedule calls for secondary waste treatment facilities to be construction and in operation by 1976. Established river water quality classification following implementation is Class B. Therefore, if the existing EPA-State implementation schedule is met, the NEWS study has no reason to believe the water quality would not be suitable for diversion.

Comment: Recommend the discharge of diverted water into the western branch of Quabbin Reservoir rather than the middle branch.

Response: The location of the outlet for the Northfield Mountain project has been a subject which received considerable attention during the NEWS study. Based on the studies conducted, the majority of investigations; including consultants, some Public Health Service engineers and Metropolitan District Commission Engineers; conclude that flexibility should be built into the outlet system. Accordingly, the outlet for the diversion would discharge into the middle branch of the reservoir. However, provisions would be constructed in the tunnel aqueduct which would allow extension of a tunnel leg to the west branch of the reservoir if it is found necessary. It is felt that the flexibility of this potential "Y" outlet arrangement as proposed allows greater protection for the reservoir than a single outlet location.

Comment: The project should include the use of a monitoring device to measure radioactivity. Concern is expressed about the possibility of an accidental spill during diversion periods.

Response: The NEWS study agrees that monitoring of water quality parameters in the water to be diverted is of paramount importance. As described in an earlier response both the Northfield Mountain and Millers River Basin reports recommend the installation and maintenance of water quality monitoring stations. The location, parameters to be tested and frequency of testing would be established with consultation by the responsible Federal and State health agencies. Such detailed investigations would be an element in the Advanced Engineering and Design Phase.

Comment: More detail should be included on the possible effects on fisheries downstream from the diversion projects.

Response: Possible effects of the diversion projects on downstream fisheries in the Millers and Connecticut Rivers and the Connecticut River estuary were studied extensively. Personnel from the U.S. Fish and Wildlife Service as well as private consulting firms provided input to the study. Impacts on fisheries in the estuary are included in Section 3 - Connecticut River Estuary Study. Impacts on fisheries in the Connecticut River from the diversions were considered by all investigators to be minimal. In the Millers River Basin, the control flows established and described in the statement were designed to have minimal impact on fisheries. Therefore, the diversions considered in the Millers Basin use as a baseline, flow rates which preclude impacts on downstream fisheries.

Department of Commerce

Comment: It is not explicit whether the Millers River plans are included in the Connecticut River Diversion impacts given in Table 1 or in Figure 1.

Response: Text has been revised to clarify the inclusion of the Millers River plans in Table 1 and Figure 1.

Comment: In the discussion of public health aspects, mercury and pesticide analysis are not described consistently for the various alternatives.

Response: Text has been revised to insure consistent reporting.

Comment: Three comments were made on the section describing the potential of weather modification.

Response: Changes in text were made in accordance with comments .

Bureau of Mines

Comment: Tunneling as proposed in the projects might have some impact on the mineral resource potential. The environmental statement should include a section on the geology of the region and discuss the impacts caused by construction.

Response: A section on the geology of the region has been included in Section II - Environmental Setting Without the Project. In Section 3, B7 Environmental Impacts of the Proposed Action, a discussion of construction activities is discussed.

Bureau of Outdoor Recreation

Comment: The statement has largely failed to identify and assess recreation and open space related environmental consequences of the proposals and in particular the effect of diversions on the exhibt "R", a part of the application for Northfield Mountain submitted to the Federal Power Commission which covers the recreational resources associated with the project.

Response: We have carefully reviewed the exhibit "R" and find no points of conflict on recreation use of the Applicant's lands and associated waters with the diversion project.

Comment: The statement's discussion of the Millers River Diversion fails to specify if additional reservoir clearing or vegetation changes due to protracted inundation will have any adverse effect of recreational facilities at Tully Reservoir.

Response: As discussed on page 27 of the draft, the pool level would be held at 649 MSL between June 15 and September 15th for recreational purposes. Project operation includes summer recreational use of Tully Flood Control Reservoir.

Comment: The statement's references to transmission tunnels required for diversion do not provide sufficient detail to determine the environmental implications which might be associated with the construction or long-term operation.

Response: See Section III, B7 which discusses this point in detail.

Comment: The statement fails to consider the effect of supply rationing at present levels as a tool to stabilize interim growth of the region. The statement should be expanded to include discussion of the impact of such an alternative would have on prolonging the utility of the current water supply system.

Response: The reviewer apparently did not read the authorizing law which was included in the draft. No authority was granted under this legislation to plan for the stabilization of the region, the directive was to evolve a plan to meet the long term water needs of the northeastern United States. The directive is also discussed in some detail in the Introduction. Further discussion was included on page 150 of the draft.

Fish and Wildlife Service

Comment: Established control flow rates should be referred to as estimates which may have to be adjusted where the project is implemented.

Response: True. The control flows are estimates, which may have to be adjustei. These estimated flow rates were worked out with Bureau of Sport Fisheries & Wildlife personnel during the Planning process.

Comment: Control flows should be discussed for Tarbell and Priest Brooks.

Response: Tables presenting control flows for all alternatives in the Millers River Basin have been added.

Comment: A glossary would be helpful.

Response: A glossary has been added.

Comment: A description of the existing; sport fishery from the estuary to Holyoke Dam; commercial fishing below Hartford and efforts to restore and enhance anadromous fish runs to the river should be added.

Response: The section on the Environmental Setting Without the Project - Northfield Mountain Diversion has been expanded to include the above aspects.

Comment: The Environmental Setting Without the Project should describe the historical fish and wildlife which were once associated with the Millers River. This section should also describe the potential for trout fishing in the basin with pollution abatement.

Response: The historical fish and wildlife attributes of the Millers River Basin have been added to the section. The possible environmental enhancement of the Millers Basin by pollution abatement measures have been described in Section 3 - Environmental Impact of the Proposed Action.

Comment: The section titled Environmental Impact of the Proposed Action should include possible impacts on the environment caused by construction activities.

Response: This is described in Section 3, B7.

Comment: Reference to requirement for fish passage facilities which bar lamprey eels and their subsequent impact on Quabbin should be deleted.

Response: References cited have been deleted.

Comment: Change definition of wetlands to read "Wetlands by their definition are lowlands covered with shallow and sometimes temporary or intermittent waters, and no significant impacts are expected."

Response: Change has been made. See definition in General Responses, Section

Comment: Statement page 58 2nd paragraph should be changed to indicate that the environmental impacts on the Tully and East Branch Tully Rivers may be more significant than on the Millers River due primarily to differences in water quality and aquatic resources.

Response: This has been done.

Comment: The Tarbell Brook diversion discussion needs more consistency with the project description regarding pool size.

Response: Inconsistency caused by typing error which has been corrected.

Comment: Statement page 53, 3rd paragraph suggests rewording to read "Approximately 50 acres of valuable inland game habitat would be lost. Fishing and boating values associated with this project are expected to increase."

Response: Change as suggested made in statement.

Comment: Statement page 54, 1st paragraph, requests clarification of replacement of $\frac{1}{2}$ mile trout stream by marginal waterfowl area.

Response: Description as given in statement is sufficient to illustrate environmental impact of proposed action. No changes made.

Comment: Recommend that the list of adverse environmental effects be expanded to include destruction of fish and wildlife habitat and the environmental degradation resulting from urbanization (made possible) by delivery of this resource.

Response: Don't agree with this comment. This recommendation represents an opinion of the commenting agency. Although it may be debated that increased population in and of itself causes "environmental degradation" it does not follow that urbanization invariably causes environmental degradation. Changes in fish & wildlife habitat listed in the draft are those brought to the forefront by the Agency's representative during the planning process.

Comment: The water demand control section in the statement should include the impact of water conservation (assumed to mean education programs) for the public.

Response: The impact of public education programs on water use has been included in the statement in the Alternatives to the Proposed Action section.

Comment: The last paragraph of the Irretrievable or Irreversible Commitment of Resources Section is inappropriate and should be deleted.

Response: This section has been revised with the above mentioned paragraph deleted.

National Park Service

Comment: Editorial nature.

Response: Changes made as suggested.

Comment: State Liaison Officer for Historic Preservation should be contacted to assure no sites being considered for addition to the National Register are affected.

Response: Contact was made - no sites affected.

Comment: Impacts caused by construction activities should be described.

Response: See Section 3, B7.

Comment: Long range potential impacts of diversion on the receiver and supplier area should be assessed.

Response: Material requested is found in Section 3.

State of Connecticut
Department of Environmental Protection

General Response to Letter

The tenor of the questions relate more directly to the detailed information contained in the main Survey Report and appendixes. It must be borne in mind that the Environmental Statement cannot carry the detail of the main Report, its emphasis must be on Environmental imput.

The Department of Environmental Protection of the State of Connecticut in their reply to the Preliminary Draft Environmental Impact Statement stated the position that the project should be held up until a regional agency can be set up to determine the allowable amount of water that can be diverted from the Connecticut River and to allocate that quantity of water amongst the states in a mutually agreeable way. The Department of Environmental

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Protection feels that the existing New England River Basins Commission could serve this purpose. In addition to their position statement, the Department of Environmental Protection also offered the following comments on the impact statement.

Comment: Section I is inadequate. The CEQ guidelines require that the EIS consider the overall cumulative impacts including future actions planned. The flood skimming is a precedent for future action.

Response: The projects described in the impact statement are the only actions known to be receiving consideration. To meet demands beyond the time frame served by the projects described a number of other actions such as development of the Merrimack River are inevitable is not concurred in.

Comment: It is unclear who would administer the water diversion with regard to minimum rates and days.

Response: This responsibility would be incorporated in the authorizing legislation for the specific project.

Comment: What will be the impacts of future action for which this is a precedent? Incremental amounts may injure the health of the river.

Response: See earlier response regarding future action.

Comment: Why was 17,000 cfs chosen as the lower limit of flow acceptable for skimming. The department feels a much broader and greater number of flow levels should be evaluated.

Response: See General Response - Control Flow, Downstream Effects.

Comment: What costs will be associated with the greater concentration of pollutants in Connecticut caused by diversion.

Response: Major pollution load enters Connecticut River below diversion point.

Comment: From a water supply standpoint what will happen to Hartford when they have to use Connecticut River water.

Response: See General Response - Effect on Connecticut River Basin Water Supplies.

Comment: What are the source data for the costs on the no go option.

Response: Reference has been added to No Action Alternative.

Comment: No Action Alternative considered only losses not benefits.

Response: The section on alternatives has been expanded to include greater discussion of this aspect.

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Comment: Desalinization is a long term solution which was not considered fully.

Response: See Section 5 - Alternatives - Desalinization which has been expanded from the draft.

Comment: Waste water as a potential source of industrial water is not sufficiently developed.

Response: Section on waste water reuse has been expanded. Also see General Response - Alternatives - Waste Water Reuse in Section 5.

Comment: No cost/benefit figures were presented.

Response: Cost figures have been added.

Comment: Insufficient information on costs and benefits were given.

Response: It is felt data of sufficient detail was presented which allows an assessment of this alternative.

Comment: Other diversion sites on the Merrimack and Sudbury systems does not adequately present cost/benefits.

Response: Section has been rewritten.

Comment: Water user data is inadequate. Estimates of water savings; from waste reduction, educational, modifications of building codes and pricing elasticity should be investigated.

Response: The types of investigations stated are included in the NEWS report as concurrent recommendations to project implementation. (Also see Section 5)

Comment: Since the Corps is involved with federal funding, some alternatives may be chosen not because they are the best, but because outside funding is available only for certain options. Which of the alternatives presented would the Corps help finance and which ones not?

Response: The legislation which initiated the NEWS study did not place any restrictions on alternatives which could be considered.

Comment: The restriction alternative was not fully developed. Growth has costs as well as benefits.

Response: The section on alternatives has been expanded in this area.

Comment: The population zoning and regulation definition and analysis is inadequate.

Response: Sufficient information is presented to show this is not a viable alternative to meet the 1980 time frame.

Comment: Donor and receiver areas are in Massachusetts, but any damage to the river would occur downstream. A cost/benefit analysis should be presented.

Response: None of the investigations conducted indicated any downstream damage.

Comment: The department feels these diversions are an irreversible commitment of future diversions from the river basin since no ceiling has been determined for the river.

Response: See earlier response regarding future action.

Massachusetts Department of Commerce and Development

Comment: Recommends that additional emphasis be placed upon the beneficial economic aspects of any of the alternatives.

Response: The main report of the NEWS studies include a major section on Project Impact Analysis in which two of the accounts used are National Economic and Regional Development Ovjectives. The impact statement has been modified in the no Action Alternative to more fully describe the implications of this alternative. In addition costs for all alternatives have been added.

Massachusetts Division of Fisheries and Game

Comment: The summary sheet should qualify that no adverse effects are predicted for the mainstem of the Connecticut River and its estuary based on a control flow of 17,000 cfs.

Response: Control flow in the Connecticut River used in the report has been included in the discussion in Section 3A, 1 & 2.

Comment: The Fish and Game Department anticipates diversion will cause significant changes in fish populations and abundance at Quabbin Reservoir.

Response: No back-up data is furnished to support this opinion. We have included their statement in the appropriate section of this revised draft.

Comment: Bull heads are not considered important sport fishes in the Connecticut River in the vicinity of Northfield Mountain while yellow perch not listed in the statement are important.

Response: Reference to bullheads deleted and yellow perch added.

Comment: Catfish, based on state studies, is not an important species to anglers in the river reach under discussion.

Response: Deleted reference to catfish.

Comment: Recent studies indicate walleye may spawn in the river reach below Vernon.

Response: Reference to possibility of walleye spawning in river reach under discussion is acknowledged.

Comment: No known fish passage facilities can effectively stop migration of lamprey eels and if introduced to Quabbin, the eels could be positively controlled.

Response: Reference to requirement for fish passage facilities which bar lamprey eels and their subsequent impact on Quabbin have been deleted.

Comment: Fish and game division does not agree that "diversion into Quabbin Reservoir presents a possibility of having a negative ecological impact on the fisheries of Quabbin". They feel a significant ecological impact will eventually result.

Response: We believe our negative and their significant mean the same thing.

Comment: Reference to studies on methods of excluding undesirable species being carried out by the MDC in cooperation with the Massachusetts Division of Fisheries and Game are in error. The Fisheries and Game Division has only discussed the feasibility of such studies.

Response: Statement will be modified to reflect current agreements between the MDC and the Division of Fisheries and Game.

Comment: It is believed that a decrease in oxygen in the hypolimnion will have a profound effect on the lake trout population which is part of the present ecology of Quabbin.

Response: The magnitude of the decrease in oxygen in the hypolimnion is not expected to be such as to effect salmonoid fish. Localized depletions of oxygen have been noted in Quabbin over the past six years. This year a 17 lb. lake trout was caught in Quabbin, indicating that past depletions have not been harmful to lake trout.

Massachusetts Agricultural Experiment Station

Comment: Only minute amounts of pesticides are soluble in water. Most of it is absorbed on particulate matter and subject to sedimentation. Therefore, it is not quite agreed that evaporation can be taken as a means to remove hydrocarbon pesticides through co-distillation.

Response: Text in question has been revised to read "Finally, many highly insoluble organic materials, including hydrocarbon pesticides and organomercury compounds, which are not absorbed on particulate matter and settle out, would tend to evaporate, as they reach the relatively large surface area of the reservoir."

Commonwealth of Massachusetts
Water Resources Commission

Comment: The section discussing mercury levels is unclear because it follows references to mercury levels in fish with references to levels in water.

Response: Section has been clarified.

Comment: Reference to the potential of Quabbin drying up should be expanded to include assumptions made.

Response: Assumptions have been clarified.

Comment: The section regarding the cleansing action of high flows is unclear.

Response: Section has been rewritten.

Comment: Reference to implementation of the Tully system with regard to Quabbin Reservoir might better read Millers basin diversions.

Response: This section has been rewritten to reflect impacts of the Northfield Mountain and the preferred Millers Basin projects.

Comment: Perhaps you should explain why 12,000 cfs was chosen as one of the control flows.

Response: The 12,000 cfs value together with the wide range of diversion rates tested was intended to provide sufficient testing points such that a measureable impact could be obtained. An explanation of this rationale has been added to the statement.

Comment: Is it anticipated that shad would migrate upstream more rapidly to compensate for the 3‡ day difference in spawning maturity development?

Response: See page 85 of the draft. Explains that studies conducted under worst possible conditions (12,000 cfs at Montague City and 4,000 diversion) indicate a maximum temperature rise of .61°F. This is too small to be biologically significant so a hypothetical 2°F was used as a yard stick as explained on this page. Page 86 discusses shad migration and temperatures and the fact that they go further upstream during "colder" spring. The consultant has postulated that the most severe diversions would have an insignificant effect on shad spawning locations.

Comment: How does egg development data correllate with effect on spawning described in the statement.

Response: This is described on page 86 in the draft and is contained in this statement.

Comment: Alewives are not mentioned. Alewives and blue backs are presumed to fast as they run upstream to spawn and resume feeding when the spent fish return to brackish water.

Response: Concur.

Comment: Temperature rise is given as 72°F.

Response: Typographical error. Corrected to 2°F.

Comment: The statement relative to additional sources of heat should be qualified to conform to existing Water Pollution Control standards which relate to most sensitive use.

Response: Paragraph cited relates to one of the three assumptions which had to be made so it could be possible to calculate the changes in temperature caused by varying diversions. The paragraph has no relation to Water Pollution Control standards.

Comment: Does temperature rise of 20.4°F refer to effluent temperature above ambient or actual increased temperature of receiving waters.

Response: Reference is to temperature above ambient.

Comment: Text should include a map illustrating relative locations of Thompsonville and Bodkin Rock.

Response: Because of the scale involved, a written description has been added in lieu of a map.

Comment: "A cleaner river than otherwise possible..." might be changed to otherwise likely.

Response: This section has been rewritten and the subject sentence was not included in the rewrite.

Comment: Percentage of flow diverted from the Millers River should be included.

Response: Percentage diverted has been added.

Comment: Justification is needed for the statement that at some point in the future river water may be of better quality than Quabbin Reservoir.

Response: This statement is based on the degradation in reservoir water quality which may occur with a heavily depleted volume. If the reservoir water was degraded and river water quality improved through construction of waste treatment facilities then the river quality could be better than the reservoir's.

Comment: Alternative population trends should be examined for their impact on projections used for the projects in the statement.

Response: Recent population estimates prepared by the University of Massachusetts were compared to estimates used in the NEWS study. For the eastern Massachusetts counties of Worcester, Essex, Middlesex, Suffolk, Norfolk, Bristol, and Plymouth there was close agreement in the population total for 1990. Deviations between the estimates was 1% in 1990 for the eastern Massachusetts region, (the general service area of the projects).

Franklin County

Comment: The impact statement indicates a variety of undesirable influences will be added to Quabbin Reservoir. The statement also notes that monitoring will be performed. However, it is impossible to believe the project would be terminated if permanent damage were recorded by the monitoring.

Response: The impact statement does describe some negative impacts which may occur within Quabbin Reservoir because of Connecticut River inflow. The possible impacts described, however, must be judged in the light of water quality loss without diversion. The monitoring programs anticipated would provide a continuous check on conditions within the reservoir. If deleterious affects were observed within the reservoir additional remedial measures could be undertaken. It must be remembered that all impacts described in the statement are based on existing Connecticut River quality conditions. Proposed waste treatment plants currently included in the Federal-State implementation schedule plus the goals set forth in the Water Quality Act of 1972 will considerably improve conditions over those presently found in the river. Therefore, any possible impacts included in the statement should be minimized by the waste treatment facilities.

Comment: It is implied in all environmental legislation that quality environments should be preserved and less than desirable environments should be upgraded to meet the optimum. The impact statement defines possible impacts which could have a deleterious effect on Quabbin Reservoirs existing high quality. This is violating the intent of the environmental movement. A better solution is to utilize poor quality sources through upgrading.

Response: The reviewer perhaps missed the portion of the draft which indicates that at current use rates Quabbin would be in trouble as a "treatment plant" before it would be unusable as at water supply. It is essential that water be introduced to keep up its purification capacity.

Comment: Sport fisheries are used as the only criteria of environmental influence. Food chains which support the fisheries are not considered.

Response: See General Responses - Biota and non-sport fish.

Comment: The "report" indicates that Tully Lake will be doubled to 600 acres (Alternative No. 3 only) and used as a domestic water supply. Does this mean swimming will not be allowed? Franklin County could use additional surface water recreation activities.

Response: Correspondence received from the Massachusetts Department of Public Health notes that full recreation activities would be allowed on the impounded pool.

Comment: A fine case is made for socio-economic impacts on receiver communities. However, a similar analysis of negative impacts was not made for basin communities.

Response: Investigations conducted did not reveal widespread impacts on the basin communities as suggested by the reviewer. The section on socio-economic impacts for the basin communities has been expanded to clarify this point.

Comment: A local community, namely Orange, Massachusetts is approaching the limits of its presently available safe yield. Why wasn't this town and other basin communities provided access to the water system.

Response: The future needs of the communities in the basin was compared to available resources before any diversions were contemplated. Based on these investigations local resources are available (even after diversion) to meet their needs. In the specific case of Orange, both surface and ground water resources are available which can be developed at far less cost than connection to Quabbin Reservoir.

Comment: Athol and Orange have high unemployment rates and their overall welfare and economy are in serious trouble. If it is assumed that water supply is a resource needed to promote future growth what is the overall long term impact of removing the resource.

Response: Projections of economic growth in the subject region were prepared. On the basis of these projections the diversion projects would not affect growth potential.

Comment: Why is there no mention in the Environmental Impact Statement of a mechanism to allow the doner area to gain back the complete right of using the water resources considered in the projects.

Response: The intent of the environmental impact statement is not to act as a summary of the main study reports and thus this item was not included. However, before the Millers River Basin project was implemented enabling legislation by the Commonwealth of Massachusetts would be required. The issue raised by the reviewer probably would be considered prior to the passage of such legislation.

Comment: The question of who pays for the project is unanswered. The MDC is a state agency and therefore will the costs be allocated to the consumers or all the residents of the state?

Response: As described in the response to the prior comment enabling Massachusetts legislation would be required. At present consumers of MDC water pay all costs of the system.

Comment: As a trade off, increased recreational use of Quabbin reservoir should be allowed.

Response: The Massachusetts Department of Public Health is the responsible agency regarding recreational use of water supply reservoirs. Any additional recreation activities would have to be sanctioned by that agency.

Comment: The impact statement indicates ground water development is too costly. Costs are not given in the statement, however.

Response: Costs have been added.

Comment: What are the water demands for the Connecticut River Valley area and have they been taken into consideration?

Response: See General Response - Effect on Connecticut River Basin Water Supplies.

Comment: What will be the effects of tunnelling on the environment?

Response: See General Response -(Environmental Impacts of Construction Activities?)

)

Comment: The projects would add a resource which would allow further growth in urban areas. As a consequence Franklin County is developing into a recreational area for those in urban areas. This recreation industry is not wholly desirable and reduction of available water resources will further guide the county into a single economic system.

Response: See earlier response regarding water supply and economic projects.

City of Hartford

Comment: Opposes proposed diversions until riparian rights of the city have been recognized and provided for through adequate institutional arrangements representing jurisdictions having rights and interests and also until the implications of the proposed diversions with respect to ecological effects and future water supply needs in areas downstream have been more adequately studied and considered.

Response: Opposition statement has been included in impact statement.

Town of Montague

Comment: Diversion from the Tully Flood Control Dam and/or Tully Complex would seriously deteriorate water quality in the Millers and Connecticut Rivers.

Response: Impacts of diversion on water quality has been expanded in the statement.

Natick Conservation Commission

Comment: The statement does not offer alternative actions for resolving the real problems of water resource supply and demand. The NEWS study should work for waste-water reuse; local ground and surface water resource development; local water pollution treatment; water rate changes; programs to modify domestic plumbing; increased rates by the MDC; and use of the Merrimack River and tributaries.

Response: Alternative actions are included in Section V - Alternatives to the Proposed Action. These alternatives are given in the NEWS studies' recommendations. In addition to project implementation programs designed to educate and investigate advantages and disadvantaaes of water conservation techniques are recommended.

Connecticut Audubon Council Inc.

Comment: The comments offered by this reviewer indicate that in their opinion certain areas of the statement are not sufficiently detailed.

Response: This Final Statement has amplified the draft material and includes additional data for the greater detail requested by this and other reviewers.

Connecticut Forest and Park Association, Inc.

Comment: The draft statement fails to recognize the need for a more detailed analysis and evaluation of these and other diversions within and without the watershed of the Connecticut River.

Response: Statement represents an opinion of the reviewer.

Comment: We have concerns relative to the possibility of the diversions at Northfield and the Millers River Basin Water Supply Project being viewed by the Metropolitan District Commission as a justification for additional diversions from these and other tributaries of the Connecticut to meet other needs within the service area of the Commission beyond 1998.

Response: See General Responses - Future Actions

Comment: A disproportionate emphasis has been placed on the negative aspects of no diversion, while positive alternatives of placing reasonable limits on consumption and moving toward re-use of water in the industrial sector are de-emphasized.

Response: See General Responses - Alternatives

Comment: The examination and analysis of potential ground water supplies in Plymouth County appear to be incomplete. Economic and social cost are referred to but they are not completely analyzed. Desalinization is treated in a similar manner.

Response: The entire section on alternatives has been rewritten to present a clearer picture of the pros and cons associated with each alternative. See General Responses - Alternatives.

Comment: The statement on page 156, "... that both donor and receiver areas are within the borders of Massachusetts, so that economic benefits realized by the construction of the project would be reflected favorably on the state's economy as a whole." is fallacious.

Response: The above mentioned statement has been deleted and the section in which it appeared has been rewritten.

Comment: The diversion projects have been predicated upon a control flow of a minimum of 17,000 in the Connecticut River at Montague City. This control flow was elected not from environmental considerations but rather from existing Massachusetts State legislation which was based solely upon the hydro power generation needs at Turners Falls Dam.

Response: The control flow on the Connecticut River for the various diversion projects is specified in the existing Massachusetts Legislation relative to the Northfield Mountain project. Adoption of a control flow other than that specified by the Commonwealth of Massachusetts would be unrealistic planning. However, environmental impacts of diversions utilizing this control flow were thoroughly investigated. Examinations were made of possible environmental impacts on the Connecticut River estuary, on the river system downstream from the project intakes and on the receiving water bodies. The evaluation of possible impacts demonstrates clearly that use of the 17,000 cfs value insures minimal environmental degradation. Thus, if use of the 17,000 cfs figure as a control insures minimal environmental damage, it follows that some lower value, in fact, would be an environmental control flow rate. Use of the existing legislated minimum control flow thus provides a conservation approach to planning.

Comment: Increased water flows are being considered by the Federal Power Commission in relicensing of Turners Falls and the four immediate upstream dams (currently an additional 0.20 cfs per square mile of drainage.) it would be consistent in the Corps of Engineer's thinking to make these flows available for diversion under the current method of stream flow calculation.

Response: This comment is apparently caused by the Council's lack of understanding of the relicensing under consideration and of the Connecticut River's hydrologic cycle.

Modifications of existing flow rates are being considered by the Federal Power Commission (FPC) in relicensing of Turners Falls and the three (not four as stated) immediate upstream dams. The 0.20 cubic feet per second (CFSM) currently under consideration by the FPC in its relicensing deliberations is not an additional amount over and above those flows presently found in the river during the entire year. Rather, the 0.20 cfsm refers to maintenance of an instantaneous minimum flow rate below the power dams.

At most times of the year, flow conditions in the river exceed the 0.20 cfsm value. During low flow periods, however, operation of the power dams causes river flow to fall below this value on occasion. The FPC thus is considering relicensing the subject power dams with the stipulation that their operation insure a minimum 0.20 cfsm flow at all times, even during low flow periods.

The diversions being considered, on the other hand, would take place during high runoff periods when river flow below the power dams is far in excess of the 0.20 cfsm value. For example, the 17,000 cfs control flow used throughout the study would allow a minimum of 2.2cfsm flow downstream of the Turners Falls power dam. Thus, the planning under way for diversions and deliberations by the FPC on relicensing are fully compatible.

Comment: The Council has questioned whether there exists a "substantial surplus of water." It further states that the availability of water and the future demands for water supply have not been fully studied or planned for.

Response: See General Responses - Effect of Diversions on Connecticut River Valley Water Supplies.

Comment: It is assumed that identical impacts may occur within the donor if diversions are allowed as has been suggested to occur in the receiver area if diversions are not allowed.

Response: The situation between those communities which would receive the diverted water and the municipalities in the valley is totally distinct. On the one hand, receiver communities are faced with distinct possibilities of water shortages. The valley communities, however, would not face water shortages because of the diversions. As stated earlier, the adopted study minimum control flow requires a minimum flow of 11,000 mgd at Montague City, Massachusetts before diversions would take place. This flow is thus available for valley needs. In order to place some measure on this available quantity of flow, it is again noted that in 1960 total municipal supply used in the valley downstream from the diversion projects was 159 mgd or about only one seventieth of the control total.

In the evaluation of the project impacts, possible socio-economic impacts were assessed for the valley communities as well as for the receiver communities. The results of this investigation are summarized in the Preliminary Draft Environmental Impact Statement.

Comment: Cost estimates of ground water development should be given. More evaluation should be given to this alternative.

Response: Costs have been added and the section on ground water development expanded.

Comment: Impact of construction activities are not described.

Response: See General Responses.

Comment: More study needs to be done of alternative water supply sources in eastern Massachusetts and further environmental impact studies are needed.

Response: Further study on any issue may aid the final decision. It is felt however that sufficient study has been conducted such that a rational decision may be made on the projects under consideration.

Lower Pioneer Valley Regional Planning Commission

Comment: Use of the 17,000 cfs control flow rate is a questionable standard in light of its basis in power generation needs rather than environmental criteria.

Response: See General Response - Control Flow

Comment: Concern is expressed as to the manner of monitoring diversions.

Response: The provision of adequate gaging stations to measure diverted flow would be included in any of the alternative projects. The location of such stations would be part of the advanced engineering and design investigations.

Comment: No specific flows are proposed for Alternatives No. 1 and 3.

Response: Tables showing control flow rates have been included for all alternatives.

Comment: Should not the August, September and October control flow be maintained at no lower level than that proposed for July.

Response: The flow rates shown were developed in conjunction with the U.S. Fish and Wildlife Service and represent those values considered necessary for maintenance of the stream's fisheries resource.

Comment: Socio-economic benefits to the supplier area must be weighed against costs. Diverted waters would not be available for use by communities of the donor area. Curtailment of water supply development caused by diversion by valley municipalities may result in socio-economic problems.

Response: See General Responses - Effect of Connecticut River Basin Water Supplies.

Comment: No clarification is given as to the types and amounts of compensation that would be offerred the reparian communities.

Response: See General Responses - Effect on CRB Water Supplies.

Comment: Development of ground water supply sources in eastern Massachusetts holds promise. The statement however does not include costs.

Response: A fuller description of economic, socio-economic and environmental costs associated with ground water has been included in the statement.

Comment: Cost data given for desalinization should be documented further.

Response: See General Response - Desalinization.

Comment: A graduated water pricing system could have significant effect on demand especially for industrial users, i.e. through increased use of recycling.

Response: As described in the section on water demand control pricing for conservation objectives in the long run may have merit.

Comment: The statement lacks reference to the recently completed Connecticut River Comprehensive Study. There is no indication of how the diversion proposals fit in with this important study of the Connecticut River itself.

Response: Reference to the Comprehensive study has been added as follows: "All alternatives described were included in the 1980 Connecticut River Basin Plan prepared by the New England River Basins Commission."

Massachusetts Audubon Society

Comment: There is no program set forth in the Preliminary Draft Environmental Impact Statement which advocates an integrated program of water supply expansion and demand limitation as the means to a long term solution.

Response: It appears from the comment that the impact statement was considered to be the Report on the Northfield Mountain and Millers River Basin water supply projects. The objective of an environmental impact statement is not to act as a summary of conclusions and recommendations for a plan of action. Rather the environmental impact statement's intent is to bring together and report upon the direct and indirect environmental impacts of a project and alternatives in a separate document. Alternatives to the proposed action in turn are assessed in the context of the definition of alternative i.e. one or the other not both. To directly answer the question, yes, we recommended in the Reports that both the need for project implementation and for investigations to test methods of demand modification be carried out.

Comment: No cost estimates are presented for treatment facilities yet benefits for the clean up of the Millers River are presented.

Response: Cost estimates have been added to the statement.

Comment: Socio-economic impacts are used in the report to favor the structural approach and to damn non-structural approaches.

Response: The assessment of potential socio-economic impacts under the "go" and "no go" (or with or without adequate supply) was made by a professional consulting firm under contract to the Corps of Engineers. The charge to the consulting firm was two fold:

1. Identify changes attendant on the Northfield and Tully diversions that will affect human populations in the immediate supply area and among potential receivers.

2. Quantify or characterize those changes wherever possible in terms of magnitude, direction and duration.

Comment: Cost estimates for ground water development in Plymouth County are not given.

Response: Costs associated with ground water development have been added.

Comment: Ground water recharge, waste water reuse and the elimination of leaks were not seriously investigated.

Response: Ground water recharge was investigated and not considered a viable alternative to the proposed action. Waste water reuse is described in Section 5 - Alternatives to the Proposed Action - Waste Water Reuse as a Municipal Supply. The possible impacts of a public education and conservation program have been added.

Comment: The preliminary draft demonstrates a remarkably discretionary use of caution.

Response: This comment represents an opinion of the reviewer.

Comment: A reasonable assessment of the impact of the diversion on intermittent wetlands would be necessary in an honest statement.

Response: Stage reductions caused by diversions and impacts on "intermittent" wetlands has been expanded.

Comment: The impact of the diversion must be added to flood stage reduction by the existing system of flood control structures.

Response: The impacts tested and described in the statement represent impact extremes. If diversion impacts were considered at a time when flood control facilities were operating the impact would be even less. For example, flood flow rates on the Connecticut River at Montague City are 79,000 cubic feet per second. If the Northfield and Tully Millers diversions were operating at the same time, stage reductions would be about .2 feet. Temperature increases in the estuary under these flow conditions would be about 0.2°F.

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Comment: Non-game aquatic species are considered insignificant. Each of these species is part of a complex food web. So in reality, the interrelated assemblage of populations of such species of fish and the eco system which supports them must be considered.

Response: See General Response - **Biota and non-Sport Fish in the Connecticut River.**

Comment: The draft statement fails to describe any analysis of the impact anticipated in coastal marsh areas at the mouth of the estuary which, because of reduced freshet flow, fail to experience the reduction of salinity which is natural at freshet time.

Response: No significant impacts are anticipated in the coastal marsh areas at the mouth of the estuary. The reviewer apparently has the misconception that operation of the diversions would cause a cessation of freshet conditions in the estuary. Freshet conditions in fact would not be halted.

Comment: There is a tendency to downgrade or neglect ecological disbenefits of the proposed diversions. For example, additional fertilizer will be necessary to compensate for the loss of the annual spring flood soil enrichment; loss of biological productivity in the estuary; damage to the Quabbin fishery; loss of recreational canoeing opportunities.

Response: Possible disbeneffits are not neglected. However, the minor impacts, for example, expected on downstream flood plains (less than .1 foot stage decrease at Thompsonville) do not make a case for any substantial disbenefits. In the case of canoeing opportunities affected on the Millers River, this section has been expanded. The possible introduction of exotic species to Quabbin Reservoir appears to have been overemphasized in the preliminary draft based on statements made by the U.S. Fish and Wildlife Service and the Massachusetts Division of Fisheries and Game.

Comment: The statement fails to consider the cumulative effect on Connecticut River flood stage of the proposed diversions combined with existing diversions and flood control reductions.

Response: As stated earlier the impacts described are considered for severe conditions. During flooding conditions when flood control structures would be operated, impacts are less than those described. In addition the effects as described are based on hydrologic conditions which include the existing Quabbin and Ware diversions. Therefore the impacts as described do in fact reflect the cumulative effect.

Comment: The authors of the preliminary statement seem to be operating on the implicit assumption that all economic growth is good.

Response: In the evaluation of all of the projects, the proposed Water Resources Council guidelines were followed and benefits as well as losses were evaluated on a three account system. The guidelines were established under the premise

that the overall purpose of water and land resource planning is to reflect society's preference for attainment of the three objectives defined as:

1. To enhance the National Economic Development.

2. To enhance Environmental Quality.

3. To enhance Regional Development.

Comment: Loss of municipal revenue is not a valid measure of economic loss. This would be true only if the community is able to operate its water supply system at a net profit.

Response: A community would not have to be operating at a net profit in order to sustain economic losses from water shortages. A water system is made up of many components which must be paid for regardless of the volume delivered. For example, distribution systems which were financed by municipal bonding represent a fixed cost to the community through amortization of the bonds. If revenue from water sales is not available to pay these costs there, the municipality must transfer funds from some other part of its budget. In turn money transferred is no longer available for other municipal services.

Comment: A diversified program provides a more desirable solution than simply project implementation.

Response: See earlier response on purpose of the environmental impact statement.

Comment: A fair market value for the water diverted should be paid for by the consumers. It is certainly a violation of equity that communities in the MDC area resell Quabbin water to support their tax basis at the expense of communities along the Connecticut.

Response: It is a debatable point that consumer communities support their tax base at the expense of communities along the Connecticut. However, throughout the conduct of the NEWS study, equity has been a major design objective in the evaluation of any of the projects. Establishment of the various diversion control flow rates on the Connecticut and Millers River are one method of insuring an equitable distribution of the resource. Cost sharing rational developed for the projects for example includes provisions that the user pays the cost of the water.

Investigations conducted however did not reveal any widespread impacts to communities located downstream of the diversion intakes. Without such impacts it is difficult to argue that downstream entities are being injured and therefore entitled to compensation.

Comment: The impact statement should state explicitly the projections of demand for water and the assumptions which underlie these projects.

Response: Requested information will be found in the Introduction Section.

Comment: There should be an evenhanded and complete statement of the costs of all alternative approaches.

Response: Costs for the alternatives have been included.

Comment: The model for the economic analysis of interbasin transfers should be that included in the Draft Report of the National Water Commission.

Response: The five criteria included in the National Water Commission Draft Report for economic analysis of interbasin transfers were examined. On every count it is felt that the diversion projects under consideration meet these criteria.

With regard to the review recommendation, the projects under consideration would be subject to review by the mechanism in effect at the time of their submittal.

Comment: The preliminary draft isolates each alternative and considers it in isolation against the diversion project then discards it. The alternative of combining measures should be assessed.

Response: As required by the National Environmental Policy Act, viable alternatives to the proposed action which may lessen environmental impact must be reported upon. Alternative is by definition "an opportunity for choice between two things, courses or propositions, either of which may be chosen, but not both."

Comment: There is a notable lack of any explicit mention of land disposal of municipal sewage.

Response: In a highly urbanized area, such as eastern Massachusetts, it is difficult to find areas large enough to be suitable for land disposal of municipal sewage, considering the large quantities involved. In addition, public health authorities have expressed concern with such operations. Studies regarding use of land disposal for municipal sewage including availability of land, possible health problems, environmental and socio-economic impacts are presently being conducted by the Corps of Engineers under a separate NEWS study on wastewater management. The conclusions and recommendations for these wastewater management studies will be completed in the fall of 1974.

Comment: The socio-economic impacts are superficial, completely non-professional, biased and totally unconvincing. A neutral consultant should have been retained for the assessment of socio-economic impacts.

Response: The socio-economic impacts were performed by an independent neutral consultant under contract.

Comment: Construction impacts should be assessed.

Response: See Section 3, B7.

Comment: The statement in several places refers to "other alternatives outside the scope of the present project". It is difficult to understand the statement unless the scope of the project is, in error, defined narrowly to include only structural interbasin transfer alternatives.

Response: In the conduct of the study several contracts were let to consulting firms on portions of the investigation. The statement noted was made in one of these consultant reports and is valid with respect to his scope of services. However, the entire study considered all alternatives. The statement noted has been modified to reflect the entire study effort.

Connecticut River Ecology Action Corporation

Comment: See Massachusetts Audubon Society's responses.

Millers River Watershed Council Inc.

Comment: Can only deduce that the only concerns felt by the Corps of Engineer's study are for the possible receiver area. The fact that the transfer of water from the doner area to the receiver area could cause the same and additional problems to the donor area seems to have escaped the Corps attention.

Response: Socio-economic impacts of the diversions are described in the statement for both the supplier and receiver areas.

Comment: The Millers River only plan (Alternative No. 1) is the plan supported by the Council after clean up of the Millers River. The gaging station for such diversions should be established on the Millers River itself rather than on the Connecticut River.

Response: As described in the impact statement diversions from any of the Millers River Basin alternatives would be subject to two control flows. One of these is on the Connecticut while the second would be in the Millers River basin.

Comment: The preliminary draft environmental impact statement has lost sight of the "gut issue" in the environmental guidelines for the civil works program of the Corps of Engineers.

Response: Guidelines cited were used in the preparation of the statement.

Laura M. Stickel, E.Q. Chairman
League of Women Voters of Holyoke Area

Comment: No references are given for background data reports.

Response: References have been added to statement.

Comment: Population growth figures are outdated and too great.

Response: A comparison of population estimates used in the NEWS report and estimates recently prepared by the Commonwealth of Massachusetts do not reveal any major differences for the eastern Massachusetts region. Total population estimates for Worcester, Essex, Middlesex, Suffolk, Norfolk, Plymouth and Bristol counties used in the NEWS report differ by only 1% for 1990 from the state figures.

Comment: Communities in the "water rich"(referring to western Massachusetts?) region are restricted in their water use to a larger extent than those municipalities in the metropolitan regions.

Response: A review of communities which restricted water usage in 1966 reveals that a total of 103 Massachusetts municipalities curtailed supply to consumers to some degree. Of this total 76 communities were located in the central and eastern Massachusetts counties of Worcester, Essex, Middlesex, Suffolk, Norfolk, Bristal and Plymouth.

Comment: What will be the environmental impact of rock excavation and spoil areas.

Response: This item is addressed in Section 3, B7 of this statement.

Comment: The historical potential of diversion from the Millers River is not a valid reason for carrying out this plan today.

Response: The statement referred to was given as background information. No changes made.

Comment: Communities downstream from the diversion intakes rely upon ground water supplies. Diversion will have an adverse effect on the annual recharge of these wells and a potentially disastrous effect on these communities.

Response: See comment by David W. Stickel regarding ground water and response.

Comment: The value of fish other than those species important to anglers is not considered.

Response: See General Responses - Biota and Non-Sport Fish in The Connecticut River.

Comment: It is impossible to accept the statement "no changes are predicted for vegetative" given some areas probably will receive shorter periods of inundation. The vegetative cover is highly dependent on not only average amounts of water but on duration and season of water availability.

Response: The statement still stands. The amount of "change" in water levels and duration of flooding simply does not have the magnitude necessary to promote changes in species composition. The writer realizes the importance of water levels but also must take into account the characteristics of successful riverine plants, which, in order to be successful must be very adaptable to the changes in the river system such as temperatures and varying water levels.

Comment: I predict seasonal inundation will create a mudflat bare of vegetation promoting erosion and siltation.

Response: Represents a prediction by the reviewer. No back-up is given so we cannot respond to the reviewer's rationale.

Comment: What will happen to the water quality of the donor areas should diversion occur.

Response: Section 3, Environmental Impacts of Proposed Diversions discussion of impacts on water quality has been expanded.

Comment: The no diversion alternative is, on the contrary the most realistic.

Response: This represents an opinion by the reviewer.

Comment: The MDC at present must add any community to its system which chooses to join, provides the piping and guaranties purchase of an agreed volume annually. This creates a poor attitude toward water. Because the communities must purchase a guaranteed volume the local water resources are abandoned.

Response: Under present Massachusetts State legislation, the MDC system is required to permit any municipality within 10 miles of the State House in Boston to become a member upon application. The MDC is further bound by the same legislation to allow any other municipality within 15 miles of the State House which could be reasonably serviced by the MDC to become upon application a member. Any non-member municipality with the approval of the Massachusetts Department of Public Health can be furnished water by the MDC.

No new member outside the 10 mile limit can be admitted without a pubiic hearing and unless the Commission can show financial advantage to the District as a whole.

Although historically communities which joined the MDC turned over their local supplies for administration by the MDC in recent decades, the practice has not been followed. For example, sinec 1949 12 communities have been connected to the MDC system and retained their existing sources.

Comment: "Water rich" communities pay more for water than "water poor" arens.

Response: Costs of water charged by communities varies considerably depending on a number of variables. Included in these variables are age of system, water treatment required, number and density of service connections, pumping requirements and other engineering considerations. Comparison of prices between municipalities is not complete unless a full accounting is made of the variables (or reasons) which provide the basis for water costs.

For example retail water prices in communities serviced by the MDC vary from 27¢ to 67¢ per 1,000 gallons.

Comment: Summary sheet eliminates a number of alternatives on the basis of "cost". Diverted water is cheaper only because it is taken without dollar payment.

Response: All of the alternatives examined were evaluated on the basis of environmental, socio-economic and economic "costs" not simply on a dollar by dollar cost comparison.

Comment: Local resources should be utilized. Desalination and wastewater reuse programs must be examined for implementation.

Response: All of the items stated were evaluated for their potential in meeting future needs in the Survey Report. Additional data is also included in this statement.

Comment: Sanitary sewers must be separated from "storm sewers" in future building programs.

Response: At present building codes require new construction to separate storm and waste discharges.

Comment: Building codes must be changed to encourage water saving models for toilets.

Response: In Section 5 - Alternatives to the Proposed Action - a description of water saving appliances' possible advantages and disadvantages has been included.

Comment: Population zoning and regulations are needed to preserve the environment.

Response: This item was included in the Preliminary Draft Environmental Impact Statement - no changes made.

League of Women Voters of Massachusetts

Comment: What we question is the somewhat unbalanced values assigned to donor and receiver issues - is the loss of a lawn any more traumatic to an MDC user than the loss of a trout stream to a Tarbell Brook resident? Fish and grass are desirable though not necessarily equal elements of man's environment.

Response: The evaluation process in any project is a complex problem. In the subject project citizen input to aid in the evaluation process was sought through public progress and informational meetings. The findings included in the project report reflect information gathered at these meetings.

Comment: NEPA requires exploration of all possible alternatives to a proposed project including the alternative of no project. We feel that some of the alternatives are rejected without benefit of the depth of analysis and research given to the proposed diversions.

Response: The section on alternatives to the proposed action has been expanded.

Comment: Re water demand control figures on water use within the MDC and the manner in which this water is used must be developed before the alternative of demand control is negated.

Response: The investigation of the potential which water demand control techniques may have in meeting future needs is recommended as a concurrent action to project implementation.

Comment: Re pricing restraints, is the Siedel and Baumann assessment of the minor effect of rate adjustment relevant to MDC?

Response: The assessment attributed to Siedel and Baumann is included together with other investigators analyses on pricing impacts to give the reader the range of opinion which exists on the subject.

Comment: A number of comments interspersed throughout the League of Women Voters letter refer to the need for a better knowledge and use of how and where water is used in the communities which would be served by the project.

Response: As one of the project report's recommendations, a survey of available water usage and means to insure wise use and conservation of this supply was recommended. This investigation would proceed concurrently with further investigations of the project itself.

Lake Cochituate Watershed Association, Inc.

Comment: The benefits of water demand control should be discussed in greater detail.

Response: The entire section on alternatives has been expanded including the above referenced section.

Save Our Streams

Comment: The solutions or alternatives that the Corps has proposed are not long range solutions to the water supply-demand problem.

Response: Represents statement of the opinions of the reviewer. Not answerable as a comment.

Comment: This preliminary draft Environmental Statement is not an honest assessment of the impact the proposed diversion out of its natural watershed will have on the two watersheds.

Response: Major portions of the study effort were conducted by independent contractors who are specialists in their particular field. For example, the Essex Marine Laboratory of Essex, Connecticut carried out the research which indicated that no change is anticipated in salinity levels in the estuary during diversion periods. The point being that the Corps of Engineers went to "outside" experts to provide the necessary scientific input to the planning process.

Comment: Because the potential of the Millers River Basin as a water supply was recognized in the 1920's does not necessarily mean that the solution is a competent one, on the sole answer to the water supply problem.

Response: Agree, statement was included to describe the history of water supply planning in the region.

Comment: The statement that the socio-economic impact on the donor area is to be positive is highly questionable and a direct contradiction of the fact that there can be no guarantee made on the quality of the water at the time of diversion in the basin itself or in Quabbin Reservoir.

Response: The installation of advanced waste treatment facilities on point sources of pollution in the Millers River as part of the water supply project cannot help but have a positive effect on water quality and associated socio-economic activities.

Comment: It is a well-known fact that labor forces for the project would consist of out-of-town help.

Response: It was assumed that union labor would be employed on the projects and that some members of the affected communities belong to trade unions.

Comment: If large socio-economic impacts are to be felt by towns supplied by the Quabbin-Sudbury System in a"no-go" situation, the fault lies solely in the hands of the Metropolitan District Commission for their failure to urge conservation.

Response: The Massachusetts' legislative charge to the MDC is to supply water to member communities not to mandate the amounts and use of water.

Comment: Referring to page 150 and the section on the "imposing of Restrictions on Water Use" the reviewer feels the consumer is willing to curtail his consumption of water.

Response: Represents an opinion of the reviewer.

Comment: Page 26 refers in depth to the Priest Brook alternative. This has been repeatedly denied as an alternative by the Corps, yet it still, in fact, a viable consideration.

Response: The Priest Brook alternative was included in the statement as required by NEPA. In the project report, this alternative as well as the Millers River alone alternatives are not selected as the recommended course of action. In order to prevent further confusion to the reader the statement has been restructured to delineate clearly the preferred alternative.

Comment: Silting is obvious on Royalston Road north from a recent construction project on the Priest Brook. Yet the Corps concludes that silting is minimal. This area has a fine sand content and the lack of current survey on silting again casts doubts on the credibility of this statement.

Response: The construction project referred to by the reader is unknown to the Corps of Engineers. It may be that poor construction techniques were employed by whoever was involved. Long term records on silting within Corps reservoirs available to the New England Division, however do not reveal silting as a problem in the area.

Comment: The East Branch Tully River again is a classic example of the lack of consideration given to the natural environment by the Corps of Engineers. The eight miles of wetland definitely bound to be affected by a loss of water necessary to the riverine cycle.

Response: Because of interest expressed by many reviewers regarding wetlands, information on this subject has been expanded.

Comment: Short term solutions is amplified for the period 1989-2000 on pages 59 and 60. The statement "we envision probable changes",... shows the type of guesswork encompassed in this statement. Page 63 has a chart which diagrams the eight year period that Millers can completely handle the demand. $38 million for an eight year solution is foolish.

Response: The evaluation of environmental impacts in many cases is in its infancy. In some cases the state of the art only allows the use of professional judgement in making predictions hence use of such terms as "probable" etc. is required. The reference to 38 million for an eight year solution may be due to a misunderstanding on the part of the reviewer. The project of course would contribute to water supply needs well beyond 1990 although by itself it could not provide all the water needed.

Comment: How is it that no odor was detected at Millers River? (P. 76)

Response: Statement refers to stations on northern tributaries of the Millers River, not the main stem of the stream.

Comment: What data backs up low significance of impacts on page 79?

Response: References have been added to this revised draft Environmental Impact Statement.

Comment: On page 83, the construction phase of diversion is a definite ingredient on environmental impact. The validity of an impact statement of not including it is questionable.

Response: Requested information is found in Section III, B7 of this statement.

Comment: No guarantee diversion below the presently postulated limits.

Response: The diversion rates tested as described in the statement are far in excess of those proposed in the considered projects. Diversion rates below these tested values such as those in the proposed action would cause even less effect.

Comment: Chloride table dated 1935-1937 is insidious by its inclusion.

Response: The 1935-1937 study of the salt content of the Connecticut River was the most comprehensive undertaken up to the present time . Scientists of the Essex Marine Laboratory, Essex, Connecticut who conducted our Lower Connecticut River studies were convinced that Meade's information on salinity represented the salt condition of the river today.

Comment: There is no basis for the astounding, ridiculous statement that there will be no appreciable impact on the Millers River Watershed.

Response: Reviewers apparently misread the statement as it reads "that there will be no appreciable impact on the hydrology of the Millers River Watershed, although a greater effect will be noticeable on the Millers River mainstem since a larger percentage of water will be diverted during the diversion period.

Comment: Current high record rainfall has continued into 1973. This should be included.

Response: It is discussed.

Comment: Show that people are willing to conserve, per the National Wildlife Federation Survey (1972).

Response: Impacts described are based on the reactions of "case study" community which has suffered water shortages recently.

C. Russell Shaw

Comment: Disturbed by easy acceptance of public disapproval of water use restrictions. It seems essential that public education on water conservation should proceed rapidly.

Response: The alternative of public education and conservation programs has been added to the impact statement. Although it is concluded such programs are not in and of themselves alternatives to the proposed projects such education programs are included in the study report's recommendations.

Jean A. Simoneau

Comment: With regard to the description of the Priest Brook Diversion, there is also a tree farm containing more acreage than the combined holdings of the trailer park and rod and gun clubs.

Response: Reference to a tree farm in the project area has been added.

Comment: In Section 7 - Irretrievable or Irreversible Commitment of Resources reference to "Structure can be removed and the land restored to its former condition" is fallacious and misleading.

Response: This section has been revised with the above mentioned reference deleted.

Comment: The statement "nearly all reparian rights along the reaches of Tarbell and Priest Brooks affected by the proposed diversion are controlled by the Corps of Engineers Birch Hill Dam" does not portray accurately land ownership in the project areas.

Response: The statement referred to is in a paragraph describing the effect of reduction in stage in the stream reaches downstream of the diversion intakes. No reference to land ownership is made or intended.

Comment: The impact statements' assessment that the Priest Brook project will not affect endangered species or bird habitat is hard to believe.

Response: Reviewer miscontrued the term endangered species. This refers to a list of such species kept by the U.S. Bureau of Sport Fisheries and Wildlife. This list is reviewed by the Corps of Engineers to insure that no endangered species would be affected by the project and a statement to that effect is included in each project environmental impact statement.

Comment: Socio-economic impacts as described in the impact statement are not based on hard data.

Response: The measurement of socio-economic impacts is far from an exact science. However, in assessing such impacts the services of a consulting firm with experience in such impact analysis was utilized.

Warren M. Sinclair

Comment: Description of waste treatment plants required on point sources of pollution should read "advanced waste treatment plants".

Response: Correction as suggested has been made to text.

Comment: The exact position of flow monitoring stations should be spelled out.

Response: The exact location of flow monitoring stations would be a subject included in the advanced engineering and design phase. However, the various alternative descriptions regarding such flow monitoring stations has been altered to point out that such stations would be located both upstream and downstream on the river in which an intake is located. For example, gaging stations would be located upstream and downstream in the Millers River itself for any plan involving the Millers River.

Comment: Is the 17,000 cfs control flow used for the Connecticut River appropriate.

Response: See General Response - Connecticut River Control Flow.

Comment: There appears to be a conflict in degree of flood protection from Alternative No. 2. One sentence reads "also provides flood control protection " while another reads "protection is minimal."

Response: Sentences in the statement regarding possible flood control protection have been revised to note the minor additional benefits from this plan.

Comment: The statement includes the sentence "Some 30 miles of streams would become excellent quality". The location of this sentence leads the reader to believe tributary water quality would be improved where they are excellent quality present.

Response: Sentence referenced has been moved to impacts on the Millers River portion of the discussion.

Comment: Sentence which reads "... it must be borne in mind that Alternate No. 1 or No. 2 would not be implemented until water quality of the Millers River meets all public health as well as environmental standards present at Quabbin" would infer that the difference between the two plans is 8 mgd.

Response: The sentence reference should have read "... it must be borne in mind that the Millers River portion of Alternate No. 1 or No. 2 would ...".

Comment: Stage development of the Millers River project using Alternative No. 1 as the recommended project with the Tully portion of Alternative No. 2 as a back up appears to be a reasonable approach.

Response: Because of uncertainties regarding use of the Millers River when needed, Alternative No. 2 (with the Tully River) was chosen as the preferred project. If authorized the project would move to the advanced engineering and design phase. During this phase the suitability of the Millers River water quality based on tests performed at that time would be reexamined. If the rivers' quality were found suitable for diversion at that time, the risk of using the Millers River alone would no longer be an element in the project selected for construction. In other words the design and construction sequence provides considerable flexibility in choosing the project actually constructed.

David W. Stickel, Assistant Professor of Biology,
Holyoke Community College

Comment: Abbreviations are used for which no definitions are given.

Response: A glossary has been added to the statement.

Comment: No references are given for background data reports.

Response: References have been added to statement.

Comment: Typing errors noted.

Response: Corrected in statement.

Comment: Costs of groundwater development should be included.

Response: Cost data is now given in the statement.

Comment: Questions adoption of 17,000 cfs at Montague City control flow and the environmental baseline this flow rate signifies.

Response: This item is addressed in General Responses - Connecticut River Control Flow.

Comment: Concrete information that diversions will not have a detrimental effect on the donor and recipient area is lacking.

Response: The information contained in the impact statement is not tended to insure that project impacts are not detrimental! Rather the intent is to define areas of environmental concern such that they may be assessed in the project evaluation.

Comment: Statement lacks sound data on the effect of diversion on basin groundwater supplies.

Response: The United States Geological Survey (USGS) were asked for their expert opinion on whether diversions as proposed would affect groundwater supplies. The USGS replied that in their opinion no significant impact would occur with the proposed diversions.

In the comment stated, reference is made to a paper [1] presented at the 1971 New England Conference on River Diversions and a quote from the referenced paper is included. An examination of the technical report from which the conference paper was drawn, however, reveals the conclusion that diversions 4 times those discussed in the impact statement "would not decrease the river's recharge capability to any noticeable extent."

Comment: Information is lacking as to the environmental impact of construction and annual cleanup of spoils.

Response: This item is addressed in Section 3B 7.

Comment: Costs of desalted water are given for present technology not for future potential and desalination is best solution.

Response: This item is addressed in General Responses-Desalination.

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[1] Role of Connecticut River Flood Flows in Recharging Groundwater Formations by Oswald C. Farquhar.

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New England Chapter Sierra Club,
Connecticut River Basin Task Force

Comment: Diversification with development of alternative sources of supply should be undertaken for several reasons. Surface water sources is particularly susceptible to pollution. A statement prepared by Western Mass. Electric Co. indicates Connecticut River water contains phenols, copper, lead and zinc which may impede use of this source for water supply. It should also be noted that Millers River water will at times be drawn upstream by pumping the water through the Northfield Mountain pumped storage intake.

Response: At present a number of surface water sources are used to furnish supply to the Quabbin-Wachusett-Sudbury Reservoir system. In the Connecticut River basin, the Swift River with its highly protected watershed furnishes water to Quabbin. In addition a separate river, the Ware under adopted sanitary regulations is diverted to Quabbin during high flow periods. The Wachusett and Sudbury Reservoir systems are each supplied water by separate tributaries of the Merrimack River Basin. In addition to the existing diversification of sources now used for supply purposes in the main reservoir system, there also exists within a number of the serviced municipalities independent supplementary sources both surface and ground. This existing configuration of available sources offers a degree of flexibility and protection to consumers.

Water quality investigations of the Connecticut River were conducted as part of the NEWS report. On the basis of those investigations, water quality in the Connecticut River was found to be suitable for use after storage in Quabbin. It is anticipated that existing river water quality will be significantly improved following planned pollution control measures. In order to insure continuing high quality water within the system, a monitoring program is included in the reports recommendation section.

The reference to Millers River water being drawn into the Northfield Mountain intake refers to a low flow condition. The contemplated diversion would occur during high flow periods.

Comment: Changing economics resulting from improved technology and periodic reassessment of priorities should be factors in weighing alternatives. For example, desalination in the future may provie economical.

Response: The statement's analysis of alternatives to the proposed action is based on present state of the art. Prior to actual construction of the project the then state of the art of alternatives together with priorities would be reevaluated.

Comment: Flood waters are necessary to the salt: fresh water balance in the estuary. The success of the anadromous fish restoration program depends on the excess flow of fresh water in the Connecticut River in late spring time.

Response: These items are considered and described in 3A-1 and 3B-1.

Comment: The importance of developing ground water supplies have been badly under emphasized.

Response: The section on the ground water alternative has been expanded.

Comment: The use of Quabbin waters for flushing purposes should be re-examined for the Chicopee and Charles River.

Response: To our knowledge Quabbin water is not used for flushing the Chicopee and Charles River. Water released from Quabbin is in accord with a U.S. Supreme Court ruling. Re regulation of Quabbin Reservoir releases were investigated and are described in Alternatives to the Proposed Action.

Comment: A reorganization of priorities within the MDC is urged. The South Sudbury and Cochituate Reservoirs and the Sudbury River should be cleaned up and used in the system.

Response: The potential of utilizing portions of the Sudbury system is under investigation by the MDC.

Comment: Finally, the concept that what is good for Boston is good for the Commonwealth should be reconsidered.

Response: Represents an opinion of the reviewer.

GLOSSARY OF ECOLOGICAL TERMS

Below is a list of ecological terms which are used frequently by personnel of the Environmental Resources Section when writing Environmental Impact Statements and other correspondence.

Terms underscored in a definition are separately defined in this Glossary. Where appropriate, closely associated or related terms are cited parenthetically, (See. ---), following the definition.

ACCLIMATION- Physiological and behavioral adjustments of an organism in response to a change in environment. (See Adaptation).

ADAPTATION- Change in structure, form or habits of an organism to better fit changed or existing environmental conditions. (See Acclimation).

AEROBIC- Refers to life or processes occurring only in the presence of free oxygen. (See Anaerobic)

ALGAE The simplest of all plant forms having neither roots, stems, nor leaves. Algae forms the base of the food chain in aquatic environments. Some species may create a nuisance to other life forms when environmental conditions are suitable for prolific growth.

ANADROMOUS- (A-NA-DRO-MOUS) Pertains to those fish that spend most of their life in salt water but enter freshwater to spawn; e.g. salmon, shad, striped bass, etc. (See Catadromous)

ANAEROBIC- Refers to life or processes occurring in the absence of free oxygen. (See Aerobic)

APHOTIC ZONE- An area within the water column in which light does not penetrate with sufficient intensity to maintain photosynthesis. (See Euphotic Zone).

AUTOTROPHIC- (AU-TO-TRO-PHIC) Self nourishing; denoting those organisms that do not require an external source of organic material but can utilize light energy and manufacture their own food from inorganic materials; e.g. green plants. (See Heterotrophic)

BENTHOS- Collective term for organisms attached or resting on the bottom or living in the bottom sediments of oceans or lakes; e.g. oysters, clams, worms, attached algae, flounders. (See Nekton, Demersal, Pelagic).

BIOMASS- The total amount of living material in a particular habitat or area; or, an expression dealing with the total weight of a given population of organisms.

BIOTA- All life of a region.

BOD (biochemical oxygen demand) A measurement of the amount of oxygen required by aerobic (oxygen demanding) organisms (usually bacteria) in the decomposition or break-down of organic matter. (See COD)

BRACKISH WATERS- Those areas where there is a mixture of fresh and salt water.

CARNIVORE- Pertains to an animal that feeds on other animals. (See Herbivore, Omnivore)

CATADROMOUS- (CA-TA-DRO-MOUS) Pertaining to fish that spend most of their life in freshwater, but migrate to the sea to spawn; e.g. American eel. (See Anadromous).

COD (chemical oxygen demand) - Measurement of the oxygen equivalent of that portion of the organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant. (See BOD)

COMMUNITY- An assemblage of populations living in a prescribed area or physical habitat; all the populations occupying a given area; the living portion of the ecosystem.

COPEPODS- (CŌ-PE-PODS) A group of minute aquatic organisms (about 0.1 inches long) that have rounded bodies and a pair of elongated oarlike swimming appendages; found everywhere in shallow waters and part of the open-water plankton of ponds, lakes and oceans. (See attached figure)

DEMERSAL- (DE-MER-SAL) Pertains to those aquatic organisms that live near the bottom of a body of water. (See Benthos, Pelagic, Nekton)

DETRITUS- (DE-TRI-TUS) The mass of non-living matter composed of dead organisms (and their fragments) and the inorganic constituents such as clay particles and sand grains.

DIATOM- (DĪ-A-TOM) A single-celled algae encased in an intricately etched pair of silica shells that fit together like a box and its lid; they occur abundantly as floating forms in plankton. (See attached figure)

DIURNAL - 1. Refers to an event, process, or specific change that occurs every day, usually associated with changes from day to night.

2. Pertaining to those organisms that are active during day time.

ECOLOGY- The study of the relation of organisms or groups of organisms to their environment; the science of the inter-relations between living organisms and their environment; study of the structure and function of nature; the science of the living environment; environmental biology.

ECOSYSTEM- A unit in which the community and the non-living environment function together.

EMBRYO- (EM-BRY-O) An early developmental stage of an organism produced from a fertilized egg.

EPILIMNION- In a thermally stratified lake, the uppermost layer which extends from the surface to the thermocline; (See attached map, also Thermocline, Hypolimnion)

ESTUARY- That portion of a coastal stream influenced by the tide of the body of water into which it flows; a bay, at the mouth of a river, where the tide meets the river current; an area where fresh and marine waters mix. (See Brackish)

EUPHOTIC ZONE- The lighted region of a body of water that extends vertically from the water surface to the depth of effective light penetration. (See Aphotic Zone)

EURY- Prefix denoting a wide range of tolerance of an organism to a specific environmental factor; e.g. euryhaline refers to salinity; eurythermal refers to temperature. (See Steno)

EUTROPHIC- Term generally applied to a shallow, highly productive body of water which possesses an extensive littoral zone with plant growth and is rich in the basic nutrients. (See Oligotrophic)

EUTROPHICATION- The natural process of the maturing (aging) of a lake; the process of enrichment with basic nutrients leading to increased production of organic matter.

FOOD CHAIN- The transfer of food energy from the source in plants through a series of organisms with repeated eating and being eaten.

GENUS- A rank category in the Taxonomic classification for a group of very closely related species. (Ex: the white perch, Morone americana, and the striped bass, Morone saxatiles, are very closely related species and have therefore been placed into the genus Morone). (See Species)

HABITAT- The specific type of place or location where an organism lives. (See Niche)

HERBIVORE- An organism that feeds on plant material. (See Carnivore, Omnivore)

HETEROTROPH- (HĒ-TER-O-TROPH) An organism which must obtain both inorganic and organic raw materials from the environment for survival. (See Autotroph)

HYPOLIMNION- In a thermally stratified lake the zone which extends from the thermocline to the bottom; usually devoid of oxygen and high in carbon dioxide. (See Epilimnion, Thermocline and attached map)

INVERTEBRATES- Animals without an internal skeletal structure (without a backbone); e.g. insects, clams, lobsters. (See Vertebrate)

LITTORAL- (LĪT-TO-RAL) A relatively shallow area within a body of water which extends from the shore to the edge of a deep hole (freshwater) or the edge of the continental shelf (oceanic waters).

NANNOPLANK-TON- Very minute plankton not retained in a plankton net equipped with No. 25 silk bolting cloth, (mesh, 0.03 to 0.04 mm).

NATALITY- The rate at which new individuals are produced; the birth rate.

NEKTON- Collective term for the actively swimming organisms in oceans and lakes. (See Benthos, Pelagic, Demersal)

NICHE- An organism's way of life; its "occupation."

NUTRIENTS- Elements, or compounds essential as raw materials for organism growth and development; e.g. carbon, oxygen, nitrogen, phosphorous, etc.

OLIGOTROPHIC- Term generally applied to a relatively deep body of water which lacks an extensive littoral zone and is poor in dissolved nutrients; plankton is usually scarce and productivity is low. (See Eutrophic)

OMNIVORE- An animal which may subsist on plant foods, animal foods, or both. (See Herbivore, Carnivore)

PARASITE- An organism living on or within a host organism, more or less detrimental to the host. (See Symbiosis)

PELAGIC- Habitat zone comprising the open waters of a basin. (See Nekton, Benthos, Demersal)

PHYTOPLANKTON- Collective term for the plants of the plankton. Unattached microscopic plants subject to movement by wave or current action. (See Zooplankton)

PHOTOSYNTHESIS-A biochemical process by which organisms manufacture sugar or other carbohydrates from inorganic raw materials with the aid of light and pigments such as chlorophyll.

$$CO_2 + H_2O + \underset{\text{Sunlight}}{\overset{\text{Energy from}}{}} \xrightarrow{\text{chlorophyll}} \underset{\text{carbohydrate unit}}{CH_2O} + O_2\,(\text{by product})$$

PLANKTON- Collective term for passively floating or drifting plants (phytoplankton) and animals (zooplankton) in a body of water; consists largely of microscopic organisms.

POLLUTION(water) Those man-induced changes in the water which are damaging to the uses which other men make or might make of those waters, and of their products. Any impairment of water quality that adversely and unreasonably affects the subsequent beneficial uses of such water.

POPULATION- A collective group or organisms of the same species occupying a particular area.

PRODUCTIVITY- The rate at which energy is stored by producer organisms (chiefly green plants) in the form of organic matter which can be used as food material .

PROLIFIC- Pertaining to organisms that have a high reproduction rate and normally produce large numbers of young.

RESPIRATION- The complex series of chemical and physical reactions in all living organisms by which the energy and nutrients in food is made available for use. Oxygen is used and carbon dioxide released during this process.

SERE- Any given stage in the ecological succession of communities.

SESSILE- (SĔS-SIL) Pertaining to those organisms that are permanently attached to a surface and are not free to move about.

SPECIES- A category of taxonomic classification below genus rank defined as an organism or organisms forming a natural population, or groups of populations, that transmit specific characteristics from parent to offspring. (e.g. the white perch, Morone, americana . Each species is reproductively
(genus) (species)
isolated from other species with which they might breed. Hybrids, the results of interbreeding, usually exhibit a loss of fertility.

STENO- Prefix denoting a narrow range of tolerance of an organism to a specific environmental factor; e.g. stenohaline refers to salinity; stenothermol refers to temperature. (See Eury)

SUCCESSION - (ecological) The orderly process of community change; the sequence of communities which replace one another in a given area.

SYMBIOSIS- (SYM-BI-O-SIS) The intimate living together of two organisms of different species for mutual or one-sided benefit. (See parasite)

TAXONOMY- Classification of organisms with reference to their relationship (resemblances and differences) in the plant and animal kingdom.

THERMOCLINE- The transition zone between the warm epilimnion and cold hypolimnion of stratified bodies of water; zone of rapid drop of temperature with depth; temperature equals or exceeds 1°C (1.8°F) for each meter (39.37 inches) of depth.

VERTEBRATE- Animals that have an internal skeletal system (with a backbone); e.g. fish, man. (See Invertebrate)

ZOOPLANKTON- The animals of the plankton; unattached microscopic animals that have minimal capability for locomotion. (See Phytoplankton).

List compiled by Robert J. Leger-Environmental Resources Section

APPENDIX A

COMMENTS RECEIVED

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Mansfield Professional Park, Storrs, Connecticut 06268

December 15, 1972

Mr. John Wm. Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

We have reviewed the Preliminary Draft Environmental Statement for: The Northfield Mountain and Millers River Basin Diversion proposals of the Northeast Water Supply Study.

The effects of the proposal as set forth in this statement are outside our area of responsibilities; therefore, we have no comments.

Sincerely,

Robert L. Hilliard

Robert L. Hilliard
State Conservationist

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
29 Cottage Street, Amherst, Massachusetts 01002

December 18, 1972

Mr. John Wm. Leslie, Chief
Engineering Division
New England Division, Corps of Engineers
Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

We have reviewed the Preliminary Draft Environmental Statement (November 1972) for the Northfield Mountain Water Supply Project, Miller's River Basin Water Supply Project of the NEWS Study with regard to the environmental aspects related to our areas of expertise. I have consulted with the State Conservationists in Vermont and New Hamphire and we have no comment to offer on this statement.

We appreciate the opportunity to review and comment on this proposed project.

Sincerely,

Dr. Benjamin Isgur
State Conservationist

cc: K. Grant
D. Burbank (N.H.)
C. Right (Vt.)
T. C. Byerly

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Federal Building, Durham, New Hampshire 03824

November 29, 1972

Mr. John Leslie
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts

Dear John:

We are referring the Preliminary Draft and Environmental Statement for the Northfield Mountain Water Supply Project and the Miller's River Basin Water Supply Project to Dr. Benjamin Isgur, State Conservationist, Soil Conservation Service, Amherst, Massachusetts, for review and comment.

His response to you will represent the Soil Conservation Service's views on this project.

Sincerely,

D. G. Burbank

Donald G. Burbank
State Conservationist

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
337 Cowesett Avenue, West Warwick, Rhode Island 02893

November 21, 1972

Mr. John Wm. Leslie, Chief
Engineering Division
Department of the Army
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

The Soil Conservation Service in Rhode Island has reviewed the Preliminary Draft Environmental Statement for: The Northfield Mountain and Millers River Basin Diversion proposals of the Northeast Water Supply Study.

The physical effects of this proposal do not touch on any of our areas of responsibility. Therefore, we have no comment.

Sincerely yours,

Austin L. Patrick, Jr.
State Conservationist

c

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE , 96 College St., Burlington, Vermont 05401

December 1, 1972

Mr. John Leslie
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts

Dear Mr. Leslie:

In regard to the review of the Preliminary Draft and Environmental Statement for the Northfield Mountain Water Supply Project and the Miller's River Basin Water Supply Project, Dr. Benjamin Isgur, State Conservationist, Soil Conservation Service, Amherst, Massachusetts, will respond for the Soil Conservation Service as per your request.

Sincerely,

Craig M. Right
State Conservationist

cc: Dr. Isgur
R. Davis
D. Burbank
H. Hilner

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
AREA OFFICE
BULLFINCH BUILDING, 15 NEW CHARDON STREET
BOSTON, MASSACHUSETTS 02114

AREA OFFICES
Boston, Massachusetts
Hartford, Connecticut
Manchester, New Hampshire

January 24, 1973

REGION I
REGIONAL OFFICE
BOSTON, MASSACHUSETTS

IN REPLY REFER TO:

Mr. John WM. Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Subject: New England Division, Corps of Engineers
Preliminary Draft Environmental Statement
Northfield Mountain Water Supply Project
Miller's River Basin Water Supply Request

We have evaluated the preliminary draft environmental impact statement for the subject project. The project involves solutions for meeting future water supply requirements for Eastern Massachusetts and explores various alternative ways to meet the projected needs for this region. Proposals include diversion during high flow periods from the Connecticut River via the Northfield Mountain pumped storage facility directly to Quattin Reservoir and by three other alternative methods to utilize and transport water from the Millers River Basin to the Quattin Reservoir.

The review of the statement was made based on the areas of the Department of Housing and Urban Development's responsibility and expertise were taken from CEQ Guidelines, April 23, 1971, and include land use and management planning in urban areas with respect to Parks, Forests and Outdoor Recreation, Flood Plains and Watershed areas.

Our evaluation indicates that the statement as submitted is adequate and that it does not impact on HUD projects. The statement also appears to cover adequately the environmental aspects of the project.

We do recommend that the proposal be reviewed by the appropriate areawide planning agencies to determine consistency with Comprehensive Water Planning in those jurisdictional areas.

This agency has no additional comments with respect to the Preliminary Draft Environmental Impact Statement.

Sincerely,

David L. Myers
Assistant Director for
Planning and Relocation

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U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION ONE
990 Wethersfield Avenue
Hartford, Connecticut 06114

November 24, 1972

IN REPLY REFER TO: 01-06.3

Mr. John Wm. Leslie
Chief, Engineering Division
Department of the Army
New England Division,
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

NEDED-R
Preliminary Draft Environmental Statement for: The Northfield Mountain and Millers River Basin Diversion proposals - Northeast Water Supply Study

Dear Mr. Leslie:

We have reviewed the subject Draft Environmental Statement and have determined that it has no adverse affect on the Federal-aid highway program within the State of Connecticut.

Sincerely yours,

Lud Harris.

For: A. J. Siccardi
Division Engineer

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION ONE
612 J.F.K. FEDERAL BUILDING
BOSTON, MASSACHUSETTS 02203

IN REPLY REFER TO:

December 22, 1972

Mr. John Wm. Leslie, Chief
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts

Dear Mr. Leslie:

Please be advised that we have no significant comments on the Draft Environmental Statement for the Northfield Mountain and Millers River Basin Diversion proposals of the Northeast Water Supply Study.

We appreciate the opportunity afforded to us to review the Draft Statement.

Very truly yours,

E. Elinsky

E. Elinsky
Acting Division Engineer

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION ONE
219 Federal Building
Concord, New Hampshire

IN REPLY REFER TO:

December 26, 1972

Mr. John W. Leslie
Chief, Engineering Division
New England Division
Corps of Engineers
Department of the Army
424 Trapelo Road
Waltham, Massachusetts

Dear Mr. Leslie:

Subject: Draft Environmental Impact Statement
Northfield Mountain and Millers River Basin
Water Supply Projects

We have reviewed the subject draft EIS, submitted by your November 13, 1972 letter, and it does not appear that your proposed projects will have any significant effect on our highway program in New Hampshire.

Thank you for the opportunity to comment.

Sincerely yours,

F. T. Comstock

F. T. Comstock, Jr., P.E.
Division Engineer

FEDERAL POWER COMMISSION
REGIONAL OFFICE
26 Federal Plaza
New York, New York 10007

December 21, 1972

Mr. John W. Leslie
Chief, Enginering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

We have received your Preliminary Draft Environmental Statement for the Northfield Mountain and Millers River Basin Diversion proposals of the Northeast Water Supply (NEWS) Study.

Our principal concern with developments affecting land and water resources is the possible effect of these developments on bulk power facilities, including potential hydroelectric developments, and on natural gas pipeline facilities. The proposed Northfield Mountain diversion project would use a high flow skimming technique principally during the spring run-off period.

The diversion of 375 mgd, when Connecticut River flows are high, would not affect the power operations of the Northfield Mountain pumped storage project. It is anticipated that about 1100 acre-feet of additional storage in the upper reservoir would be provided as would the necessary head works and connecting aqueduct to Quabbin Reservoir.

We appreciate the opportunity to comment on this matter.

Sincerely,

John H. Spellman

John H. Spellman
Regional Engineer

OFFICE OF ECONOMIC

EXECUTIVE OFFICE OF THE PRESIDENT
WASHINGTON, D.C. 20506

January 10, 1973

Mr. John Leslie
Chief, Engineering Division
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Re: Draft Environmental Statement
Northfield Mountain and
Millers River Basin Division
Massachusetts

Dear Mr. Leslie:

Phillip Sanchez, the Director of the Office of Economic Opportunity, has asked me to respond to your letter regarding the draft environmental statement on the above mentioned project.

This office in coordination with our Regional Office and the affected community action agencies have carefully reviewed this statement. On the basis of information from this review, we have no reason to believe that the proposed action will have an adverse environmental impact on the low income neighborhoods involved. Should we receive any further information we will advise.

We appreciate the opportunity to comment on this draft statement.

Sincerely,

Arthur J. Reid, Jr.

Arthur J. Reid, Jr.
Director
Intergovernmental Relations

The Commonwealth of Massachusetts
Metropolitan District Commission
20 Somerset Street, Boston 02108

December 28, 1972

Mr. John William Leslie
Chief, Engineering Division
Department of the Army
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Sir:

I have been requested by the American Water Works Association to submit any suggestions or recommendations regarding Preliminary Draft Environmental Statement for the Northfield Mountain and Millers River Basin Diversion proposals of the Northeast Water Supply Study, copy of which enclosed herewith.

I have taken the liberty of sending you a copy of my report.

Very truly yours,

Allan Grieve, Jr.
Director of Water Division and
Chief Water Supply Engineer.

AG/AM

Enc.

The Commonwealth of Massachusetts
Metropolitan District Commission
20 Somerset Street, Boston 02108

December 28, 1972

Mr. Cliff Atkinson, Jr.
Secretary, Resources Division
American Water Works Association
704 National Press Building
Washington, D. C. 20004

Dear Mr. Atkinson:

In accordance with your request of December 7, 1972, I am submitting the following comments on the Preliminary Draft Environmental Statement for the Northfield Mountain and Millers River Basin Diversion proposals of the Northeastern Water Supply Study.

This is a very comprehensive report involving solutions for meeting future water supply requirements for Eastern Massachusetts and the possible environmental impacts. Cooperation of the various Federal, State and local agencies has been very good. Many public meetings have been held to furnish information and solicit comments on the various proposals.

The present water supply situation in Eastern Massachusetts is very critical. With sharply increasing water consumption, plus the request of additional communities to join the Boston Metropolitan Water District, it is becoming more difficult to fill Quabbin our main storage reservoir. The present year, 1972, has had above normal rainfall. However, it does not preclude the obvious and critical need to augment the existing system with additional sources. The total consumption from the Metropolitan District Commission water system has exceeded its safe yield for the last four years, which clearly indicates the serious need to immediately undertake a program to augment the supply.

The following is taken from the report of the Metropolitan District Commission relative to the diversion of excess water from Millers River and other sources into Quabbin Reservoir as requested by Chapter 66 of the Massachusetts Resolves of 1971.

"Failure to augment the existing supply system could turn the apparent advantage of the 1972 surplus into a condition wherein a water crisis of monumental proportion could occur beyond the next ten-year span which could impact adversely upon those communities which are presently served and those communities which must be served in the future by the Metropolitan Water System."

Additional sources of water are necessary for the Metropolitan District Commission to continue to supply its users with an adequate water supply. Further, these additional sources are needed in the very near future if a serious water shortage which would affect 40% of the population of Massachusetts is to be averted.

The amount of water that may be diverted at Northfield Mountain is limited by Massachusetts law for over a three consecutive year period to 375 million gallons per day for each day that the Connecticut River flow exceeds 17,000 c.f.s. at Montague City. Diversion is prohibited by law on any day when flow is less than 17,000 c.f.s. (Chapter 766 of the Acts of 1970).

The diversion of any flows above 17,000 c.f.s. at Montague City in Massachusetts would seem to be sound resource management.

Chapter 803 of the Acts of 1972 authorized and directed the Metropolitan District Commission to make studies of and prepare comprehensive plans and programs for the further development of its water supply system for the purpose of providing the cities and towns which are members of the Metropolitan Water District, the cities and towns which are eligible to become members of said district, and other municipalities of the Commonwealth which are obtaining, or in the future may obtain, all or a portion of their water supply from the facilities of the Commission.

The New England River Basins Commission recommends continued evaluation for adverse environmental effects throughout project planning, development and operation, with mitigation of environmental damage or repair by removal of the cause.

Transfer of excess flows from the Connecticut River Basin in considered an essential short term solution and is therefore not considered inconsistent with a long term strategy of satisfying resources needs through sound management of population and economic growth patterns.

As stated in the report, "The planning process, which included extensive engineering studies and an assessment of the biological and environmental data accumulated during the study period, did not uncover any irreversible actions or drastic effects on the area environment."

The consensus of opinion is that no real or substantial injury, damage or adverse effect will result from the proposed diversions. No significant changes in the hydrology, water quality or general ecology is expected in the main system of the Connecticut River.

I would recommend that the American Water Works Association generally endorse the concepts identified in the report with regard to the ecological, environmental, and public health aspects of the various proposals.

It is also recommended that appropriate action be taken if future studies reveal the risk of any adverse environmental impact.

Very truly yours,

Allan Grieve, Jr.
Director of Water Division and
Chief Water Supply Engineer.

AG/AM

STATE OF NEW HAMPSHIRE
CONCORD 03301

OFFICE OF GOVERNOR

DIRECTOR OF COMPREHENSIVE PLANNING

December 13, 1972

Mr. John William Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

The Draft Environmental Statement relative to The Northfield Mountain and Millers River Basin Diversion proposals of the Northeast Water Supply Study has been reviewed by this office, and we concur with the Statement as written and have no additional comments.

As the designated State Clearinghouse under the provisions of Circular A-95, we distributed the Statement to other interested state agencies for their review. Enclosed are copies of the responses and comments we have received.

Sincerely,

Alexander M. Taft

Alexander M. Taft

AMT/as

Enclosures

STATE OF NEW HAMPSHIRE

INTER-DEPARTMENT COMMUNICATION

DATE November 27, 1972

FROM Mary Louise Hancock, Director
Office of State Planning
AT (OFFICE)

SUBJECT Draft Environmental Statement for the Northfield Mountain and Millers River Basin Diversion Projects

TO Raymond P. Gerbi, Jr.

In view of the remoteness of this project and the absence of any tangible direct impact on the State of New Hampshire, we have chosen not to submit any formal review. Since nearly two hundred fifty parties were sent copies as part of the review process, we feel we can better expend our energies on other matters.

MLH:mb

INTER-DEPARTMENT COMMUNICATION

DATE November 27, 1972

George Gilman
Commissioner

AT OFFICE Department of Resources & Economic Development

Office of the Commissioner

Preliminary Draft Environmental Statement for:
The Northfield Mountain and Millers River Basin
Diverson proposals of the Northeast Water Supply
Study

Raymond P. Gerbi, Jr.
Assistant to the Director
Office of Comprehensive Planning
State House

This Draft has been referred to staff and the Department offers no comment.

George Gilman
Commissioner

GG:c

The State of New Hampshire

Water Supply and Pollution Control Commission
Prescott Park
P.O. Box 95—105 Loudon Road
Concord 03301

December 26, 1972

Mr. John W. Leslie, Chief
Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

RE: NEDED-R

Dear Mr. Leslie:

Regarding the Northfield Mountain project, we have no comments as the entire project is apparently outside the jurisdiction of New Hampshire.

Regarding the Millers River diversion project, there appears to be no adverse effect on any waters within the jurisdiction of New Hampshire. We, of course, cannot commit the future use of those parts of the project area within New Hampshire jurisdiction.

Yours very truly,

Stephen W. Leavenworth, P.E.
Associate Sanitary Engineer

SWL/hyv

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

Department of Administration
STATEWIDE PLANNING PROGRAM
265 Melrose Street
Providence, Rhode Island 02907

January 2, 1973

Mr. John Wm. Leslie
Chief, Engineering Division
New England Division, Corps of
Engineers
Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

This is to inform you that this agency has reviewed the Environmental Impact Statement for the Northfield Mountain and Millers River Basin Diversion proposals (reference NEDED-R) in accordance with OMB Circular A-95.

After having reviewed the proposals and having been in contact with other state agencies on the matter, we have no comments to make on the draft statement at this time.

Yours very truly,

Daniel W. Varin
Chief, Statewide Planning

DWV/TC/ln

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION
JOHN F. KENNEDY FEDERAL BUILDING, BOSTON, MASSACHUSETTS 02203

January 12, 1973

Mr. John W. Leslie, Chief
Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

We have reviewed the draft environmental impact statement for Northfield Mountain and Miller's River Basin Water Supply Projects. We are concerned about the impact of this project on the Quabbin Reservoir and the suitability of the water quality of the rivers involved in this diversion.

The Environmental Protection Agency would like assurance that the turbidity of the water entering the Quabbin Reservoir will be low. The final impact statement should state how turbidity will be monitored and controlled. We recommend that turbidity units not exceed five Jackson units. We agree with the Massachusetts Department of Public Health Directive which recommends that diverted waters be chlorinated prior to the entry into Quabbin Reservoir. The final statement should indicate the proposed effectiveness of the chlorination in reducing pollution loads and should indicate how other impurities untreatable by chlorination, will be controlled.

Pollution abatement plans for the Connecticut River are important in controlling the introduction of pathogens into the reservoir. In order to guarantee the purity of Quabbin Reservoir the final impact statement should indicate modifications in the proposed project that will be made if the water quality is not found suitable for diversion in 1976.

In order to provide maximum resident time and maximum dilution, we recommend the discharge of diverted waters in the western branch of the reservoir. By doing this, the discharge point will be a maximum distance from the withdrawal point. If the diversions are discharged in the middle branch, we feel that there is a chance

of water short-circuiting the withdrawal point, thus minimizing natural purification benefits.

The project should include the use of a monitoring device to measure radioactivity. We are concerned about the possibility of an accidental spill during times of diversion. The final statement should indicate the method that will be used.

We have been assured that there will be little fluctuation in the river level since water will be diverted only during times of maximum flow. The final statement should give more detail on this subject by assessing the effect of this project on fisheries downstream. Until we receive this detailed information in the final statement, we cannot assess adequately the environmental harm created on the river itself.

We are looking forward to reviewing the final impact statement.

Sincerely yours,

Joan Harrison

Joan Harrison
Environmental Impact Coordinator

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THE ASSISTANT SECRETARY OF COMMERCE
Washington, D.C. 20230

December 28, 1972

Mr. John W. Leslie
Chief, Engineering Division
Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

The draft environmental impact statement for The Northfield Mountain and Millers River Basin Diversion proposals of the Northeast Water Supply Study, which accompanied your letter of November 13, 1972, has been received by the Department of Commerce for review and comment.

The Department of Commerce has reviewed the draft environmental statement and has the following comments to offer for your consideration.

It is not explicit whether the Miller's River plans are included in the Connecticut River diversion impacts given in Table 1 (p. 58). Is the Miller's River diversion included with the Connecticut River diversion in Figure 1?

In the discussion of public health aspects (pp. 43-48) mercury analyses are reported for the Connecticut and Miller's Rivers but not for the Tully River or Wachusett Reservoir. Pesticide analyses are reported only for the Connecticut River.

The section on the use of weather modification as an alternative to the proposed action is generally well covered. We have three rather minor comments specifically related to this section.

(1) Page 115, third paragraph, line 5

Substitute "National Oceanic and Atmospheric Administration" for "United States Weather Bureau."

(2) Page 116, second paragraph

Evidence gained through National Oceanic and Atmospheric Administration (NOAA) research suggests that winter cloud systems over Lake Erie may be modified to produce additional precipitation. This will not alter the conclusions reached by the Corps of Engineers, namely, much research remains to be done to improve the state of the art of weather modification and, at present, reliance upon cloud seeding is not the best solution to problems of augmenting Eastern Massachusetts water supply. However, the Corps of Engineers should be aware of proposed NOAA weather modification research in the Great Lakes Basin.

(3) Page 117, first paragraph, lines 8-9

Suggest rewording along the lines, ". . . most precipitation would be taken up by plants and soil."

We hope these comments will be of assistance to you in the preparation of the final statement.

Sincerely,

Sidney R. Galler

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

OFFICE OF THE DIRECTOR

United States Department of the Interior

BUREAU OF MINES
WASHINGTON, D.C. 20240

December 20, 1972

ER-72/1345

Memorandum

To: Chief, Engineering Division, New England Division, Corps of Engineers, Waltham, Massachusetts

Through: Assistant Secretary--Mineral Resources DEC 29 1972

From: Director, Bureau of Mines

Subject: Preliminary draft environmental statement, Corps of Engineers, Northfield Mountain and Miller's River Basin Water Supply Projects of the Northeast Water Supply Study, Franklin, Middlesex, and Worcester Counties, Massachusetts

We have reviewed the preliminary draft environmental statement concerning possible water supply proposals under consideration for the purpose of providing water to the Boston Metropolitan District. The statement is a general treatment of the potential impact from obtaining a supplementary water supply from four alternate sources via Northfield Mountain and Miller's River water basins. The supplementary supply would be diverted into the existing Quabbin Reservoir.

Mineral production in the general area of the project includes sand and gravel and stone. In 1970, production was valued at $1.5 million in Franklin County, $13.8 million in Middlesex County, and $4.0 million in Worcester County. Soapstone as well as feldspar and other pegmatite minerals have been produced in the area, although there has been no production in recent years. There are also inactive lead, zinc, and graphite mines in the vicinity of Tully Mountain.

Tunneling, as proposed in the project, might have some impact on the mineral resource potential. The environmental statement should include a section on the geology of the region. It is suggested that such a discussion be included in Section II, Environmental Setting Without the Project. Then, Section III, Environmental Impacts on the Proposed Action, could discuss

any environmental impacts caused by construction. Although we do not believe the project will have any major impact on mineral resources or mineral activities, we believe a brief discussion of geology and possible mineral involvement is necessary for the statement to be complete.

Acting Director PAUL ZINNER

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF OUTDOOR RECREATION
FEDERAL BUILDING
1421 CHERRY STREET
PHILADELPHIA, PENNSYLVANIA 19102

IN REPLY REFER TO:

Mr. John Wm. Leslie
Chief, Engineering Division
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Mr. Leslie:

Mr. Bruce Blanchard, Director of the Office of Environmental Project Review, U.S. Department of the Interior, has asked us to reply directly to your November 13, 1972 letter with the Bureau's comments on the preliminary draft environmental statement for the Northfield Mountain and Millers River Basin Diversion proposals of the Northeast Water Supply Study.

The draft statement has in most instances addressed the technical and hydrologic consequences of implementing diversion of Connecticut River and Millers River water into Quabbin Reservoir to augment the municipal water supply for Metropolitan Boston. Unfortunately, with the exception of limited discussion of the environmental effects of reduced river flows and the short term effect of reduced water supply for urban Massachusetts, it has largely failed to identify and assess recreation and open space related environmental consequences of the proposals.

In regard to the Northfield Mountain, the draft statement fails to mention the effect of the proposed water supply diversion on the recreational features of the project which are included in Exhibit R of the current application to the Federal Power Commission for an operating license. Copies of the Department of Interior's comments of January 14, 1972 (FPC #1889)

and of February 14, 1972 (FPC #2845) have been enclosed for your information as part of this response. While the Federal Power Commission has not acted upon these recommendations as yet, the pending nature of the license operation deserves special consideration in the environmental statement in regard to possible adverse or beneficial effects on recreation.

The statement's discussion of the Millers River Diversion fails to specify if additional reservoir clearing or vegetation changes due to protracted inundation will have any adverse effect of recreational facilities at Tully Reservoir.

The statement's references to transmission tunnels required for diversion do not provide sufficient detail to determine the environmental implications which might be associated with the construction or long term operation. These references in the statement should be expanded and furthermore should include consideration of mitigation measures to reduce visual and physical impacts, as required, for the length of the structure.

In the discussion of short term needs for augmenting water supply, the statement indicates that demand reduction techniques at the present time are ineffective yet the statement fails to consider the effect of supply rationing at present levels as a tool to stabilize interim growth of the region. Technically, no action is a single purpose alternative and the no growth aspect associated with such an alternative could provide a means of prolonging the utility of the present water supply system while allowing sufficient time to develop long term independent alternatives. At the same time, such action would represent an opportunity to consider and resolve socio-environmental problems which will be intensified indirectly by your alternative which assumes, encourages, and enhances the present rate of growth of Southeastern New England. We believe the statement should be expanded to include discussion of the impact such an alternative would have on prolonging the utility of the current water supply system.

We have provided these comments to you for technical assistance purposes and we hope they will assist you in further developing your statement.

Sincerely yours,

Earl C. Nichols

Acting Regional Director

Enclosure

United States Department of the Interior

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

Dear Mr. Plumb:

This is in reply to your letter of October 16, 1970, requesting our views and comments on a license application by the Western Massachusetts Electric Company for the Turners Falls Project (FPC No. 1889) located on the Connecticut River, Massachusetts. We have reviewed the licensing information and submit the following comments for your consideration and use.

The Department of the Interior has participated in the Connecticut River Basin Comprehensive Study as well as the Connecticut River National Recreation Area Study. We have also made an on-site inspection of the Turners Falls Project. Based on these studies, information provided by the applicant, FPC's 1968 Evaluation Report, and the Massachusetts Statewide Comprehensive Outdoor Recreation Plan, we find the applicant's Exhibit R to be deficient. The continued operation of the project should not have a significant adverse effect on the recreation use of the area, so we would have no objection to relicensing the project from a recreational standpoint provided that the applicant prepare an acceptable Exhibit R.

The outdoor recreation needs and potential of the project area have been documented in several studies and reports. Among these, the Connecticut River Basin Comprehensive Water and Related Land Resource Investigation indicates that only 25 percent of the recreation boating potential of impounded waters within the Connecticut River Basin is being utilized and that the recreation potential of hydroelectric projects is not being utilized. A significant portion of the present and future outdoor recreation needs of this region could be met through realization of the potential inherent in the Turners Falls Reservoir. The present Exhibit R does not contain a plan which adequately provides for optimum public outdoor recreation use of project land and waters.

We note that the Turner Falls Reservoir serves as the lower pool for the Northfield Mountain Pumped Storage Project (FPC No. 2485) and that the applicant states in the Exhibit R "this proposed Exhibit R augments proposals made under the Northfield Mountain project and the development of facilities is geared to complement and support a comprehensive plan approved by the Massachusetts Department of Natural Resources and the Federal Bureau of Outdoor Recreation." However, we find that the proposals incorporated in

the license for the Northfield Mountain project provide for two actions that are directly related to the Turner Falls project; (1) the construction, operation and maintenance of the Four Mile Brook area, and (2) the acquisition of land for the Pauchang Brook area which is to be made available to the Commonwealth of Massachusetts. Due to local opposition we understand that the Four Mile Brook area is being proposed for deletion from the Northfield Mountain Project. Therefore, the remaining area in the Northfield Project will only partially assist in providing for the utilization of the full recreation potential of the Turners Falls Project.

Any license issued for this project should include the standard terms and conditions relating to recreation use and development that are contained in the appropriate FPC L-Form.

The Connecticut River in the project area supports large and small mouth bass, chain pickerel, walleye, yellow and white perch, northern pike, bullheads, channel catfish, crappie and carp. Upstream runs of the catadromous American eel, the anadromous American shad, alewife, Atlantic sturgeon and salmon are blocked by project dams. Brook, brown and rainbow trout inhabit the tributaries and are occasionally found in the main stem. The upstream portion of Turners Falls pond (the tailrace of Vernon hydroelectric plant) provides good trout fishing in the spring. Fishing pressure is moderate in the river reach from the dam upstream to "The Narrows"; northward the pressure is lighter and the Barton Cove area is fished heavily. Historically American shad ascended the river to the base of Bellows Falls, upstream from the project area. Atlantic salmon were able to negotiate the difficult rapids and ascended the river further upstream to Beecher Falls near Canaan, Vermont.

Public Law 89-304 approved October 30, 1965, authorized the Secretary of the Interior to initiate with the several states a cooperative program for the conservation, development and enhancement of the Nation's anadromous fish. As a result of this Act, the fish and wildlife agencies of the States of Vermont, New Hampshire, Massachusetts and Connecticut, the National Marine Fisheries Service and our Bureau of Sport Fisheries and Wildlife have been engaged in a coordinated program to restore the runs of American shad and Atlantic salmon in the Connecticut River since December 21, 1966. In this behalf, both a Policy Committee and a Technical Committee for Fisheries Management have been established under the terms of a formal agreement.

Several biological studies conducted by the Technical Committee have established that the Connecticut River provides suitable American shad and Atlantic salmon habitat upstream from Turners Falls Dam. Goals have been established for fish passage at each barrier dam in the river based on quality and extent of the upstream habitat. Engineering parameters for fish passage facilities have been developed for Holyoke, Turners Falls, Vernon, Bellows Falls and Wilder Dams.

The report on the Comprehensive Basin Study of the Connecticut River Basin now being considered by the Connecticut River Basin Coordinating Committee recommends that fish passage facilities be provided at five main stem dams including the Turners Falls Dam, to accomplish the objectives of the anadromous fisheries restoration program. The Secretary of the Interior, in cooperation with the Technical Committee for Fisheries Management of the Connecticut River Basin, has specified a 1973 date for completion of fish passage facilities at Turners Falls Dam.

The Policy Committee for Fisheries Management of the Connecticut River Basin has recommended that the instantaneous minimum flow released from the five major dams on the Connecticut River, Wilder, Bellows Falls, Vernon, Turners Falls and Holyoke be not less than 0.25 feet per second per square mile of drainage area (CFSM). Thus, the minimum instantaneous flow requirement for Turners Falls is 1780 CFS in order to develop and maintain the anadromous fish runs in this section of the river.

The pond facilities of the Turners Falls Project will be modified as described in FPC Order 541 to provide additional volume required for pump storage use. To accomplish this, bascule and tainter spillway gates will be enlarged to raise the pool 5.4 feet, thus deepening the shallow water areas of Barton Cove and degrading the waterfowl habitat found there. Raising the water level would not create a comparable amount of shallow water habitat elsewhere. The project otherwise will have no significant effect on wildlife.

The applicant's Exhibit S indicates that consideration is being given to the construction of a fishing platform downstream of Cabot Station. Provisions may have to be made for the closure of portions of the reservoir, river and power canal to fishing to insure fisherman safety at the project. The final decision on the feasibility of a fishing platform and possible special regulations regarding fishing in or adjacent to project facilities should be deferred until final operational procedures are implemented.

The recreational use plan is fully compatible with Exhibit S at the present time. As the impacts of pollution abatement and environmental protection and enhancement programs develop greater and more attractive opportunities for outdoor recreational uses, including those relating to fish and wildlife, both Exhibits R and S should be updated to meet increasing demands. We recommend that Exhibit S be amended to include provisions for periodic review in cooperation with the appropriate Federal and State agencies to determine future fish and wildlife development needs.

The project will not adversely impact on the mineral resources or the mineral industry. The project will not impact on any Indian lands under the jurisdiction of this Department. We believe the inclusion of the standard stream gaging article in any operating license will be satisfactory to us. However, the Turners Falls Project must be modified to provide fish passage facilities and a minimum instantaneous flow if the project is not to conflict with the on-going Federal-State program to restore anadromous fish in the Connecticut River. Subject to these requirements and the other Departmental concerns expressed in this review we do not recommend a Federal recapture of this license nor do we object to the issuance of a new license. We do make the following recommendations to the Commission:

1. The applicant be required to prepare a revised and acceptable Exhibit R prior to the issuance of any license. The revised plan should include the following:

   (a) Provisions for the immediate development of the facilities included in the three designated recreation areas: Cabot Woods, Branch Canal, and Unity Park.

   (b) Identify the additional lands at Turners Falls Reservoir which are required to help meet future outdoor recreation development needs at the project with an indication of the location, size and ownership of these lands.

   (c) The location, type and number of the various recreation facilities planned for future development.

   (d) Provisions for the development of boat access areas in the upper reaches of the Turners Falls Reservoir, particularly on the west bank.

(e) A plan for recreation development and use of lands in the 2.7 mile stretch of the river between the dam and Cabot Station Powerhouse.

(f) Provisions for biennial review and updating in cooperation with the appropriate Federal, State and local agencies to assure that acquisition and development are undertaken to meet the needs as they arise.

We further recommend that the revised Exhibit R be prepared in cooperation with our Bureau of Outdoor Recreation, the Massachusetts Department of Natural Resources, other appropriate agencies, and the licensees for the Northfield Mountain Project (No. 2485) to assure that the full potential of the project is realized and that the revised plan is consistent with the Northfield Mountain recreation proposal. In the event that the licensee does not own adequate lands to meet the future recreation needs at the Turners Falls Project, then in keeping with the Commission policy the Exhibit R should indicate the measures that will be taken to acquire and include within project boundaries enough land to assure the optimum development of the recreation potential of the project.

2. In order to provide for the conservation and development of the fish and wildlife resources it is requested that the license contain the standard conditions relating to fish and wildlife as contained in the appropriate FPC L-Form. The following special conditions are also recommended for inclusion in any license issued for this project.

(a) The licensee shall construct, operate and maintain or shall arrange for the construction, operation and maintenance of appropriate fish passage facilities at the Turners Falls Project by 1973 in accordance with the parameters set forth by the Technical Committee for Fisheries Management of the Connecticut River Basin. Final design drawings of the fish passage facilities shall be submitted to the Secretary of the Interior for approval prior to construction of the facilities.

(b) The licensee shall modify project operations as may be necessary to provide an instantaneous discharge of 0.25 CFSM (1730 CFS) through Turners Falls Dam as recommended by the Policy Committee for Fisheries Management of the Connecticut River Basin for purposes of developing and maintaining an anadromous fish run in this section of the Connecticut River.

At the time this licensing information was sent out for review by the Federal agencies the responsibility for carrying out the requirement of the Federal Water Pollution Control Act rested with the Department of the Interior. Since then this responsibility was assigned to the Environmental Protection Agency (EPA). To maintain continuity in the Federal review process we shall also list the water quality control concerns of EPA for your consideration and use.

The present water quality in the immediate area of the Turners Falls Project, although variable, is generally good and continues so as far downstream as the Holyoke Dam in Massachusetts. Downstream of this dam the water quality begins to deteriorate with a reduction in dissolved oxygen concentration and changes in other water quality parameters indicative of a degradation in water quality. The minimum level of dissolved oxygen concentration occurs in the vicinity of the Massachusetts - Connecticut State line.

The States of New Hampshire, Vermont and Massachusetts have generally classified the Connecticut River from its source to the Holyoke Dam as Class B. Below the dam the river is classified as Class C. Waters of B classification are suitable for recreation, including body contact sports, excellent fish and wildlife habitat and, after adequate treatment, public water supply. Class C waters provide for uses similar to those of Class B with the exception of water contact sports. Areas below the Turners Falls Project have been excepted from approval and are the subject of continuing negotiations.

The project operation in the past includes periods of much reduced or negligible discharge to reaches of the Connecticut River downstream of the project. In general, the impact of this type operation, during periods of low discharge, adversely affects the water quality by reducing natural recreation capacity of the stream, increasing concentrations of introduced pollutants, thereby increasing oxygen demand and by decreasing stream velocities which causes settling of suspended matter. Because of the demand for high quality water and for continual upgrading of present waters by more efficient treatment adequate streamflow is a vital consideration.

Water quality criteria for Class B waters of Vermont and Massachusetts require, in part, that the dissolved oxygen level be not less than 75 percent of the saturation level during at least 16 hours of any 24-hour period, and not less than 5 mg/l at any time. New Hampshire's criteria requires not less than 75 percent of the saturation level. Based on flow estimates at the Massachusetts-Connecticut State line, there is indication that by 1980 a flow of approximately 1500 CFS would be necessary to achieve this 75 percent level and by the year 2020 a flow of 3200 CFS will be required. Inherent in these estimates are assumptions that waste sources will be adequately treated by 85 percent removal of the oxygen demanding wastes and that all flows will be continuous.

Analysis of streamflow data for eight unregulated rivers in the Connecticut River Basin indicates that the average 60-day low flow with a 10-year return period amounts to 0.19 CFS of flow per square mile of drainage area (CSM). On a similar basis the 90-day flow averages 0.22 CSM. We believe that a flow equivalent to 0.2 CSM represents a low flow which could reasonably be expected under most natural conditions.

In view of the relationship of the project and its potential effect on downstream water quality and the maintenance and enhancement of long-term uses which will be provided by high quality water, it is recommended that the license include provisions which would permit the establishment of specific flow requirements as follows:

> The Licensee shall, in the interest of maintaining water quality in the Connecticut River, provide such facilities or modify operation as ordered by the Federal Power Commission upon the recommendation of the Massachusetts Division of Water Pollution Control or by the Water Quality Office of the Environmental Protection Agency after notice and opportunity for hearing.

As stipulated in Section 21(b) of the Federal Water Pollution Control Act of 1970, State Certification of reasonable assurance that applicable water quality standards will not be violated must be obtained within three years of the date of the Act (by April 3, 1973).

We appreciate the opportunity to submit our views and comments on this license application by the Western Massachusetts Electric Company

Sincerely yours,

(sgd) W. H. Lyons

Deputy Assistant Secretary of the Interior

Honorable Kenneth F. Plumb
Secretary
Federal Power Commission
Washington, D. C. 20426

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

Dear Mr. Plumb:

This is in reply to your letter of October 5, 1971, requesting our views and comments on an amendment to Article 41 of the Federal Power Commission license for the Northfield Mountain Pumped Storage Project (FPC No. 2485). The following comments are submitted for your consideration and use.

The outdoor recreation needs and potentials of the project area have been documented in several studies and reports. In our August 12, 1966, letter to you concerning this project we noted that the Connecticut River could be developed to provide outstanding outdoor recreation opportunities for the people in this heavily populated area. We further noted that the area lacked sufficient recreation facilities to meet the needs of the people and that the proposed Northfield Mountain pumped storage recreation development would help to satisfy these needs.

The Commission in Opinion No. 541, Opinion and Order Issuing and Amending Licenses for Project Nos. 1889 and 2485 (issued May 14, 1968) recognized the recreation importance of this project. Article 41 of the license for Project No. 2485 provides that the licensees shall expend $1,350,000 in the initial development of recreation resources and shall be responsible for the development of the Four Mile Brook area and shall purchase and make available to the Commonwealth of Massachusetts the land required for the Pauchaug Brook area. We understand that the land for the Pauchaug Brook area has been acquired by the licensees.

The proposed amendment to Article 41 would delete development of the Four Mile Brook area and would provide that funds be devoted to the development of other recreational resources. However, the proposed amendment does not designate a specific replacement for the Four Mile Brook area. Also we find that the licensees have not fully

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implemented Article 41 of the license by planning for and providing the additional initial developments required to meet demonstrated public needs at the project. In foregoing the Four Mile Brook recreation development, the recreational use plans for both Turners Falls and Northfield Mountain are affected since the planning at both of these projects was interrelated. We also believe there is an immediate need for recreational development in this area.

We recommend that approval of the Amendment to Article 41 of the Northfield Mountain license be conditioned with the stipulation that within six (6) months after the date of the approval the licensees will:

1. Provide a suitable replacement for the Four Mile Brook area.

2. Prepare an acceptable time schedule for the expenditure of the monies provided by the license for the acquisition of lands and development of facilities required for meeting the initial recreation needs of the project.

Emphasis should be given to the development of sites along the Connecticut River between the Massachusetts, Vermont, New Hampshire border and Turners Falls Dam, which are referenced on page 7 of Opinion No. 541.

We also recommend that the licensees prepare amendments to Exhibit R within one year of the date of the approval of Amendment to Article 41 to reflect, where appropriate, the following information:

1. The location of the lands planned for future development.

2. The location, type and number of various recreation facilities planned for future development according to anticipated demand.

3. A time schedule as to when these facilities will be provided.

4. Identification of the facilities shown for future development that are to be provided at the sole expense of the licensees and those facilities which will be provided in cooperation with others,

5. The location of the facilities to enable the State Fisheries and Game Department to carry out the trout stocking program which was planned for the Four Mile Brook impoundment.

We further recommend that in implementing the stipulations suggested for Article 41 of the license and in preparing the amendment to Exhibit R the work be accomplished in cooperation with the Bureau of Outdoor Recreation, the Bureau of Sport Fisheries and Wildlife, the Department of Natural Resources of the Commonwealth of Massachusetts, other appropriate agencies and the licensee for the adjacent Turners Falls Project (FPC No. 1889). This cooperative planning effort will assure that these plans complement and are consistent with the recreation proposals at the Turners Falls project.

We wish to thank you for the opportunity to review the proposed Amendment to Article 41 of the license for the Northfield Mountain Pumped Storage Project.

Sincerely yours,

(sgd) W. W. Lyons

Deputy Assistant Secretary of the Interior

Honorable Kenneth F. Plumb
Secretary
Federal Power Commission
Washington, D. C. 20426

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
U. S. POST OFFICE AND COURTHOUSE
BOSTON, MASSACHUSETTS 02109

Division Engineer
New England Division
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Sir:

This letter constitutes our review of your preliminary draft environmental statement entitled, "The Northfield Mountain and Millers River Basin Diversion Proposals of the Northeast Water Supply Study."

Our comments were prepared in response to a letter from the Chief, Engineering Division, dated 13 November 1972, and do not represent review comments of the Department.

Our comments are as follows:

1. Project Description

Alternative No. 2 - Tully-Millers Diversion

The section should include a statement to the effect that the control flows, (tables on pages 21 & 22), are estimates, not permanently set, and may have to be adjusted when the project is implemented. Control flows should be discussed for Tarbell and Priest Brooks and incorporated into the environmental statement.

Alternative No. 3 - Tully Complex Diversion

Define: cleared, grubbed and stripped. The layman may not have a clear understanding of these and other words. A glossary would be helpful.

2. Environmental Setting Without the Project

Northfield Mountain Diversion - Connecticut River Basin

This section should discuss the important sport fishery which exists in the lower river from the estuary to Holyoke Dam. Commercial fishing is primarily in that section below Hartford, Connecticut. The discussion should mention that the fish lift at Holyoke Dam has passed shad since 1955, but is inadequate to handle larger runs of salmon and shad in the future. The section should mention that a technical committee for the fisheries management of the Connecticut River Basin, formed in 1967,

is primarily concerned with the restoration of anadromous fish. The committee is made up of representatives from fish and game departments of Connecticut, Massachusetts, Vermont and New Hampshire, and the Bureau of Sport Fisheries and Wildlife and National Marine Fisheries Service.

Millers River Basin

This section should discuss the excellent trout habitat and fishing, the abundance of furbearers and other wildlife that were historically associated with the Millers River. It should be mentioned that with pollution abatement, parts of the Millers would provide an outstanding trout fishery.

3. Environmental Impact of the Proposed Action

This section should include a discussion of siltation effects in the immediate and downstream areas during project implementation; qualitative and quantitative evaluations of the wildlife habitat that will be lost by construction of the diversion tunnels or other project structures; and any methods that will be used to minimize the aforementioned adversities.

Northfield Mountain - Connecticut River

Pg. 38. The last two sentences can be deleted since there is no known fish passage facility design parameter which would effectively stop the migration of lamprey eel. In addition, passage of lamprey eels into Quabbin does not present major problems to fisheries management.

Alternative No. 1 - Millers River Mainstem

2nd paragraph - "Wetlands by their definition are wet all year round so that no impact would be expected on them," should be changed to read "Wetlands by their definition are lowlands covered with shallow and sometimes temporary or intermittent waters, and no significant impacts are expected."

Alternative No. 2 - Tully-Millers River Diversion

Pg. 51, 2nd paragraph, "It is expected that...Alternative No. 1". Should be changed to indicate that the environmental impacts on the Tully and East Branch Tully Rivers may be more significant than on the Millers River due primarily to differences in water quality and aquatic resources.

Alternative No. 3 - Tully Complex Diversion

(1) Tarbell Brook Diversion: This discussion needs more consistency with the project description. Pg. 26, 1st complete paragraph. Does the 28-acre pool inundate 40 acres of wetland or is the 40 acres inundated in addition to the 28-acre pool?

(3) Tully Reservoir Diversion

Pg. 53, 3rd paragraph. "Less than 50 acres....project would increase." Should be changed to read "Approximately 50 acres of valuable upland game habitat would be lost. Fishing and boating values associated with this project are expected to increase.

Pg. 54, 1st paragraph. "This 1/2-mile stretch of trout.....marginal waterfowl area." Clarify "replace". The trout stream will be physically replaced but the economic and aesthetic values are entirely different.

4. Adverse Environmental Effects Which Cannot be Avoided Should the Project be Implemented

We recommend that the list of adverse environmental effects be expanded to include the destruction of fish and wildlife habitat, and the environmental degradation resulting from urbanization by delivery of this resource.

5. Alternatives to the Proposed Action

Water Demand Control
B. Methods of Controlling Demand

This section should be expanded to include intensive water conservation programs for the public.

6. The Relationship Between Short-Term Uses of Man's Environment and the Maintenance of Long Term Productivity

No comment.

7. Irretrievable or Irreversible Commitment of Resources

The last paragraph is inappropriate and should be deleted.

8. Coordination With Other Agencies

No comment.

Sincerely yours,

Richard E. Griffith

Regional Director

United States Department of the Interior
NATIONAL PARK SERVICE
NORTHEAST REGION
143 SOUTH THIRD STREET
PHILADELPHIA, PA. 19106

IN REPLY REFER TO:

L7619
NER(CF)

Mr. John William Leslie
Chief, Engineering Division
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Thank you for the opportunity to review the preliminary draft environmental statement for the Northfield Mountain and Millers River Basin Diversion forwarded with your memorandum of November 14.

First, we note a few minor points of an editorial nature. On page 4, we suggest adding "ability of" to the end of line 7. On page 7, we suggest that a source from which the reports of the two environmental consultants can be obtained be listed for the convenience of reviewers who may wish to obtain them. Also, we were well into the preliminary draft before we realized that Northfield Mountain was not an alternative for one of the three Millers River diversions, but is coupled with one of them, and suggest that this point be made clear early in the statement. Finally; we feel that the statement made on page 38 that the bulk of the river's nutrient load is picked up downstream of the diversion point should be documented.

Of more concern to us are three other points. First, while we note that you have consulted the National Register of Historic Places and found that no sites listed therein will be affected, we urge that you contact the State Liaison Officer for Historic Preservation, Honorable John F. X. Davoren, Secretary of the Commonwealth, Chairman, Massachusetts Historical Commission, Office of the Secretary, State House, Boston, Massachusetts 02133, to assure that no sites being considered for addition to the Register are affected.

Second, while it is outside of our field of expertize, we suggest inclusion of more data on the possible impact of the diversion tunnels. How many cubic yards of spoil will be produced? Does disposition of this spoil create impacts? Will tunnel construction affect ground water levels or local drainage patterns and thus possibly affect localized ecological communities?

Finally, though again the subject is outside of our primary area of concern, it seems to us that the long-range potential impacts of inter-basin diversion should be discussed. If the recommendation is implemented, and the analysis of alternatives is correct, the Boston Metropolitan area will gain an additional one hundred million gallons per day of water cheaper than it could by any other method. This will permit additional growth in the Boston Metropolitan area, and thus will have a profound, if somewhat indirect effect on the environment.

Conversely, implementation of the project will remove one hundred million gallons of water per day from potential use within the Connecticut Valley, again with a profound potential impact.

We realize that an in-depth assessment of these impacts is probably not possible. We also realize that the decision as to whether or not the inter-basin diversion should be made does not lie with the Corps. Still, we feel that these long-range but profound potential impacts should at least be mentioned in the draft.

Sincerely yours,

Eugene G. Parisho

Eugene G. Parisho

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

STATE OFFICE BUILDING HARTFORD, CONNECTICUT 06115

December 21, 1972

Mr. John Wm. Leslie
Chief, Engineering Division
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Subject: Preliminary Draft Environmental Statement of the Northfield Mountain Water Supply Project on the Miller's River Basin Water Supply Project

Introduction

The Department of Environmental Protection (DEP) is gravely concerned about diversions from the Connecticut River outside of the river basin. DEP wishes to express its concern on this Northfield Mountain/Miller's River Basin Water Supply Projects, as the State of Connecticut did in 1931 with the diversion of the Swift River. We believe no State Legislature should have the sole right to determine the extent of diversions from a river which flows through other states downstream. For this reason DEP believes that a regional group should be empowered to (1) determine what is the maximum amount of water that can be diverted from the Connecticut River Basin based on the requirements of the river, the dependent eco systems and the people who live along it, and (2) allocate that amount of "divertable" water amongst states by criteria acceptable to all parties involved. DEP feels that the existing New England River Basins Commission can serve this function.

DEP's concerns about furthering the precedent of upstream diversions can be seen most clearly on Figure 1, P. 63. Quabbin and the Swift diversion started in the 1930's and according to Figure 1, it will run dry around 1984 or a period of about 50 years, a half-century. However with the proposed Connecticut diversion only, the end of Quabbin is only prolonged by about eleven years, a decade. Even with the most optimistic figures including the Tully diversions, the fate is prolonged only two decades. Clearly these are only short-term solutions. DEP's concern is that this action is a precedent for future diversions out of the Connecticut River Basin for which no impacts or controls have been discussed or dealt with, and no ongoing mechanism has been set up to handle these questions amongst states.
Therefore DEP requests that this action be stopped until a regional body such as the New England River Basins Commission can meet and develop solutions equitable to all parties involved.

In addition DEP would like to comment on the Preliminary Draft EIS by section. Our policy on the review was to consider only the points involving the State of Connecticut as there are ample reviewers from other States.

Section 1. This section is inadequate. The CEQ guidelines require that the EIS consider the overall cumulative impacts including future actions planned. DEP feels a clear statement should be made of how much water is expected to be taken in the future. This "flood-skimming" of the Connecticut River is a precedent for future action.

One area which was not covered was the administration of the water diversions. It is unclear whether the Corps will be in charge or not. Further, what control procedure will be used to insure that flood skimming only occurs on days when the minimum flows have been reached?

Section 2. No Comment

Section 3. What will be the impacts of future actions for which this is a precedent? If we continue to take incremental quantities, each diversion will be a decrease of perhaps acceptable relative amounts; however the concern should be what is the maximum amount of water which can be diverted and yet still have a healthy river. Environmental effects would be one factor in that determination.

Why was 17,000 CFS chosen as the lower limit of flow acceptable for skimming? Was this determined by projected demand for water, or were ecological reasons included? Is the Corps required to follow a State legislative mandate? DEP feels a much broader and greater number of flow levels should be evaluated. As indicated later in the EIS, this is not "flood skimming". The highest recorded CFS on the Connecticut River is in the 200,000 range. From an environmental standpoint, if 17,000 is better than 12,000, wouldn't 20,000, 25,000 or 100,000 be better than 17,000?

Socio-Economic Impacts

The analysis is too narrow. What costs will be associated with the greater concentration of pollutants in Connecticut (P.79)? Further the analysis only considers the costs and benefits to Massachusetts, but not the costs to Connecticut. This must be corrected. In addition, from a water supply standpoint, what will happen when Hartford must use Connecticut River water? The need is forecasted for before the year 2000. Hartford, however, will return the water to the river basin. What is the source data for the costs on the no go option (P. 106)?

Section 4. No discussion of impacts caused by future diversions for which this is a precedent because this project is only a short-range solution.

Section 5. In the case National Resources Defense Council, Inc. v. Morton, ___F.2d___, 3 ERC 1558 (D.C. Cir. 1972), the court found that ". . . the discussion of environmental effects of alternatives need not be exhaustive. What is required is information sufficient to permit a reasoned choice of alternatives so far as environmental aspects are concerned. As to alternatives not within the scope of authority of the responsible official, reference may of course be made to studies of other agencies--including other impact statements." (Emphasis added)

No Action. Only losses were considered. Benefits should also be considered.

Desalination

As stated on P. 121, desalination could be a long-range solution to the M.D.C.'s

problems. However the analysis in this section gives it inadequate consideration. The costs and benefits were not delineated, nor were any benefits presented.

The fact that a long-run solution was found would be a major benefit in itself. The present proposal is only a short-range solution--in ten years the problem will have to be dealt with again. Further the cost of water from the proposed plans is artificially low because M.D.C. is not paying for any costs caused by the diversion downstream. With desalination the people getting the benefits would also have to pay the costs.

Importation. No Comment

Waste Water

It is mentioned as a potential source of industrial water, but then is left insufficiently developed.

Ground Water

No cost/benefit figures were presented, so outside observers could not make a rational choice.

Dual Water Supply Systems

Insufficient information is given on costs and benefits.

Other Diversion Sites

A. No Comment

B. Merrimack River. Again costs and benefits are inadequately presented. This appears a reasonable choice for two reasons: (1) there is potential for long-run water supplies and (2) the river is closer to those who will benefit by the diversion.

Sudbury. Same inadequacies as above.

Water Demand Control

A. The data on the user area is inadequate. The EIS says national data is quite different than this region.

B. Were any efficiency studies done to determine how much of the current water is wasted in the MDC area? An educational campaign could reduce that segment and decrease future demand requirements. Modification of new construction building codes should have been considered. DEP agrees the present elasticity data is weak; however since the Army Corps is involved in several water supply projects, it should fund some water elasticity studies.

Since the Corps is involved with federal funding, some alternatives may be chosen, not because they are the best, but because outside funding is available only for certain options. Which of the alternatives presented would the Corps help finance and which ones not?

Was any consideration given to a water rate which increases with water consumed? This is an alternative that should be considered.

Restrictions

The analysis was not developed fully. As we have seen, growth has costs as well as benefits.

Release Schedules. No comment

Population Zoning and Regulations

The definition as well as the analysis of this area is inadequate.

Section 6. Donor and receiver systems are in Massachusetts, but any damage to the river would occur downstream. A cost/benefit analysis should be presented.

Section 7. DEP feels these diversions are permanent considering projected future shortages in 10-20 years. Further, this is an irreversible commitment of future diversions from the river basin since no ceiling has been determined for the river.

Conclusion

DEP reiterates its position that this is an action which definitely sets a precedent for future diversions out of the river basin. Furthermore the DEP feels that this project should be held up until a regional agency such as the New England River Basin Commission can be empowered to determine the allowable amount of water that can be diverted from the Connecticut River and to allocate that quantity of water amongst the states in a mutually agreeable way.

At your service,

Dan W. Lufkin
Commissioner

DWL:bw

FRANCIS W. SARGENT
Governor

THOMAS I. ATKINS
Secretary
Communities & Development

DANIEL P. MCGILLICUDDY
Acting Commissioner

The Commonwealth of Massachusetts

Department of Commerce and Development

State Office Building, Government Center
100 Cambridge Street, Boston 02202

727 3221

November 15, 1972

Mr. John W. Leslie
New England Division
Corps of Engineer
424 Trapelo Rd.
Waltham, Mass. 02154

RE: Preliminary draft - Environmental Statement, NEWS, Southeastern New England.

Dear Mr. Leslie:

I have had Mr. Regis J. Harrington, our Director of Area Planning, review the above identified draft statement which I received from you on November 14, 1972. We find that overall the draft statement is quite comprehensive. However, it is our feeling that the draft statement is weighted to a very great degree on the side of hydrologic parameters and a mere, so called, "brush treatment" given insofar as the economic factor are concerned in the overall environmental framework.

We feel that not enough emphasis is given to the possible economic impact portion of the environmental statement. From our point of view, this can only mean that either the Corps does not have any qualified economists on their staff or, as a matter of policy, it has been determined that the economic affects of such a proposal need not be emphsized. I wish to assure you that this Department's policy certainly emphasizes that all aspects of the environment of any project should be considered seriously. We still feel that the general public must recognize the importance of the economic aspects of any environmental statement. We all know that the "Good Life" aspects of the environment are extremely important but at the same time we should all recognize the importance of retaining and, if possible, expanding the economic base of the area in order to pay for the costs of maintaining and improving the ecological aspects of the environment.

I would therefore recommend that additional emphasis be placed upon the beneficial economic aspects of any of the alternatives described in the preliminary draft.

Sincerely,

Daniel P. McGillicuddy
Acting Commissioner

The Commonwealth of Massachusetts
Division of Fisheries and Game
Field Headquarters, Westboro 01581

2 January 1973

Mr. John Wm. Leslie, Chief
Engineering Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts

Dear Mr. Leslie:

In review of your draft Environmental Statement for the NEWS study on the Northfield Mountain Water Supply Project and the Millers River Basin Water Supply Project, the following constitutes our comment on the draft:

1. The summary sheet indicates no adverse effects are predicted for the main stem of the Connecticut River or its estuary and we believe that the statement should be qualified to indicate that no adverse effects are expected to occur providing no flows below 17,000 cfs are diverted. Also, it indicates no significant changes are predicted for Quabbin Reservoir. We anticipate that diversion will cause significant changes in the fish population complex and relative abundance at Quabbin Reservoir.

2. Page 30, paragraph 1, last sentence, indicates walleye pike, bullheads, smallmouth bass are important sportfishes in that section of the Connecticut River in the vicinity of the Northfield hydroelectric facility. This statement should be changed to eliminate bullhead and substitute yellow perch.

3. Page 37, second paragraph, second sentence, refers to species being important to anglers--walleye pike, smallmouth bass, yellow perch and catfish. Based on our studies, catfish are not important in this section of the river and should be removed from this connotation.

4. The next to last sentence on page 37 indicates the other important sportfish, walleye, apparently does not spawn in this reach of the river. Additional studies conducted by this Division now indicate walleye may spawn in this section of the river as exhibited by the collection of gravid males and females below the Vernon dam in early April.

5. Page 38, top of the page, relates to anadromous fish and expresses concern that care must be taken to design fish passage facilities that will not allow lamprey eel over the Turners Falls dam and that this

action is necessary to exclude larval lampreys from the intake, and subsequent transportation to Quabbin Reservoir. We do not believe that this is absolutely necessary as there is no known fish passage facility design parameter that will exclude lamprey eel. A firm recommendation in this regard could cause considerable delay and allow utility companies to postpone indefinitely, until positively resolved, their obligation to construct suitable fish passage facilities at Turners Falls. Based on our investigations, should larval lampreys be a problem, as with other species of fish, the best place to exclude them from Quabbin would be somewhere en route between Northfield Mountain and Quabbin Reservoir. We do not believe that lampreys would enter and cause problems in Quabbin Reservoir; however, assuming our belief to be erroneous, lampreys could be positively controlled in Quabbin Reservoir through the use of a lampricide, a selective chemical for this species used very successfully in the Great Lakes control program.

6. Page 39, first sentence, indicates diversion into Quabbin Reservoir presents a possibility of having a negative ecological impact on the fisheries of Quabbin. We do not agree with this consensus but feel a significant ecological impact will eventually result. Increased productivity and additional organic load will bring about changes in the coldwater fish carrying capabilities of Quabbin.

7. Page 40, last sentence of the paragraph continued from the previous page, indicates studies on methods of excluding undesirable species are now being carried out by the Metropolitan District Commission in cooperation with this agency. The fact of the matter is no studies are in progress and only feasibility of conducting same has been discussed with the Metropolitan District Commission.

8. Page 40, first paragraph, second sentence, indicates the magnitude of any overall decrease in oxygen in the hypolimnion of Quabbin is not expected to cause significant changes in the present ecology of the reservoir. We believe that a decrease in oxygen in the hypolimnion will have a profound effect on the lake trout population which is part of the present ecology of Quabbin.

9. The last sentence on page 40 indicates salmonid fishes in Quabbin are not expected to be affected by any lowering of dissolved oxygen localized in the upper portion of the middle arm and the eastern arm as salmonids are typically found in the main body of the reservoir. We believe a qualification is necessary, and that this will be the case only if oxygen depletion is confined to the upper portion. In previous years, density currents have been measured at Quabbin Reservoir. Consequently we feel that increased organic load will affect the main body of Quabbin.

10. Page 41, second paragraph, indicates significant levels of DDT, endrin, dieldrin, PCB's in tissues of lake trout. We would prefer that the endrin be eliminated in this report as additional studies conducted by this agency have shown that previously reported endrin was possibly in error. Also, levels of DDT now being encountered are not considered significant.

11. Page 42, the sentence in the middle of the paragraph continued from the previous page, relates to the interaction of salmonids and trash fish introduced from Northfield and states that the salmonid population could remain essentially unaffected. This would be the case providing walleyes were not introduced in the diversion. Adult walleyes are extremely predacious and would occupy the same trophic level as many of the salmonids, the net result being positive predation and competition with salmonids.

12. The last sentence of the continued paragraph on page 42 indicates that if Quabbin is not augmented with additional water, the result of ecological disaster far outweighs the above points of concern with the diversion. This statement appears to relate to general project needs without objective considerations of the existing fisheries.

In summary, from a fisheries standpoint we would have to judge the alternate diversion from the Millers main stem--your alternate 1--to have the least impact on the water quality and fish population complex at Quabbin Reservoir.

Sincerely yours,

C. H. Bridges

Colton H. Bridges
Superintendent
Bureau of Wildlife Research & Management

CHB:mb

The Commonwealth of Massachusetts
University of Massachusetts
Agricultural Experiment Station
Cranberry Station, East Wareham

November 21, 1972

Mr. John Wm. Leslie
Corps. of Engineers, Dept. of Army
424 Trapelo Road
Waltham, Mass. 02154

NEDED-R

Dear Mr. Leslie:

The preliminary draft of the Environmental Statement for the Northfield Mountain and Miller's River Basin Water Supply Projects is, in our opinion, an excellent piece of work. We witnessed the final phases of the public discussions and know how carefully the suggestions made at these meetings were considered. Although we can comment with authority on only a small section of the report, we feel that all details of the two projects have been dealt with thoroughly.

We would like to support the conclusion that pesticide residues (p. 41) will have no effect on the water quality. Approximately 200 gallons of pure chemical would be necessary to increase the residue amounts by 1 part per billion in the Quabbin Reservoir at the present water level. On the other hand, only minute amounts of pesticides are soluble in water. Most of it is adsorbed on particulate matter and subject to sedimentation. Therefore, we do not quite agree that evaporation can be taken as a means to remove hydrocarbon pesticides (p. 77) through co-distillation.

We hope that this Environmental Statement will facilitate action to solve a problem whose economic and environmental impact is not as well known to the public as it should be.

Sincerely yours,

Chester E. Cross

Chester E. Cross
Head of Department

59-652 O - 80 - Vol.II - 60

The Commonwealth of Massachusetts
Water Resources Commission
Leverett Saltonstall Building, Government Center
100 Cambridge Street, Boston 02202

OFFICE OF THE DIRECTOR
DIVISION OF WATER RESOURCES

January 12, 1973

Mr. John Wm. Leslie
Chief, New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

We have reviewed the Preliminary Draft Environmental Statement for the Southeastern New England Study, a segment of the Northeastern United States Water Supply Study. The report, together with subsidiary reports on which the statement is based, in our view constitutes general compliance with the National Environmental Policy Act. Since the study is extensive in scope but limited in duration, answers to all possible questions cannot reasonably be required. Certain questions may be answered when and if specific project proposals reach the design stage, and are subject to additional reviews, e.g., the impact of spoil areas involved with tunnel construction.

A review by various staff members has elicited several comments; some of them seeking clarification, others recommending strengthening or correction, as follows:

Page 46 - Middle, Paragraph 2

The section discussing mercury levels is unclear either because it follows references to mercury levels in fish with references to levels in water, or because one of the designations should read ppm instead of ppb.

Pages 61, 62, 63

The rather positive statement regarding Quabbin drying up is of a type which can come back to haunt its author. We believe that all the assumptions upon which the statement and figure one are based should be discussed, including not only hydrological assumptions, but per capita use projections, birth rate projections, etc. This is especially cogent since the lay public interpret Quabbin's resurgence this year as a contra-indicative of a long-term downward trend.

Page 80 - First full page

The section regarding the cleansing action of high flows is unclear. It seems the reverse of what one might logically assume.

Page 82 - Paragraph 3

Reference to "...implementation of the Tully system..." might better read "...Miller's basin diversions...", unless you have made a decision not supported in the body of the report.

Page 84 - Center of page

Perhaps you should explain why 12,000 cfs was chosen as one of the control flows.

Page 86 - Paragraph 2

Is it anticipated then that shad would migrate upstream more rapidly to compensate for the 3± day difference in spawning maturity development?

Page 86

How does Paragraph 2 correlate with Paragraph 4? Does Paragraph 4 relate to egg development after spawning.

Page 87

Alewives not mentioned? Alewives (and bluebacks) are presumed to fast as they run upstream to spawn and resume feeding when the spent fish return to brackish water. (Bigelow and Schroeder 1953. Fishes of the Gulf of Maine).

Page 88 - Paragraph 3

...temperature rise of 72° F?

Page 90 - Paragraph 3

The statement relative to additional sources of heat should be qualified to conform to existing Water Pollution Control standards which relate to most sensitive use.

Page 91 - Paragraph 3

Does the temperature rise of 20.4° F refer to effluent temperature above ambient or actual increased temperature of receiving waters?

Page 99 - Paragraph 2

Text should include a map illustrating relative locations of Thompsonville and Bodkin Rock.

Page 109 - #1 bottom

"A cleaner river than otherwise possible..." might be changed to "...otherwise likely...". It may well be that the 1972 amendments to the Federal Water Quality Act superimposes a schedule that will be difficult to meet (much less beat) under any circumstances.

Page 110 - Last paragraph

When you mention the effects on the Millers River system, you do not quantify the effects in terms of the percentage of the total annual flow diverted. This fact should be included.

Page 113

Some further justification should be made for the statement that "at some point in time, riverine waters will actually be of a higher quality than the reservoir."

In a general vein, I believe that discussion of the impact of alternative population trends on the needs and the timing of alternatives should be included. We appear to be nearing zero population growth. I think it is worthy of mention since some new projections developed at the University of Massachusetts regarding fertility rates by age groups, indicate that our population growth may be less than that ordinarily assumed.

The report will be a tool used in Federal decision-making. It may, or may not, be adopted by the state as its view in regard to the environmental impacts of these proposals. Since state guidelines have not yet been provided pursuant to Chapter 30, Section 62, we cannot comment positively as to whether the statement appears to satisfy requirements regarding the provision of environmental statements for state projects. It is, however, our present understanding that, to the degree that a statement acceptable to NEPA covers the elements of a project in which there is state participation, the Federal statement may constitute compliance with the state requirement. It is the intent that state guidelines will be similar to those followed in compliance with the NEPA.

Sincerely yours,

Charles F. Kennedy
Director and Chief Engineer

CFK:ehc/eb

best copy available

COMMONWEALTH OF MASSACHUSETTS

Franklin County

DEPARTMENT OF PLANNING

COURT HOUSE, GREENFIELD, MASS. 01301
773-3003

December 28, 1972

John W. Leslie
Chief, Engineering Division
Department of the Army
New England Division
Army Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

The Franklin County Planning Department has reviewed the Draft Environmental Statement for the Northfield Mountain water supply project and the Millers River Basin water supply project. During our review we noted certain deficiencies that cause us utmost concern. Our general opinion of the document is that the environmental impact along with the social and economic benefit heavily indicate that a bias toward the eastern part of the Commonwealth was built in. We feel that a better evaluation of the impact in the donor area is warranted. We will discuss these below.

Our specific comments fall into social, economic, and biological impacts.

1. In the discussion of the report on the impact of the Quabbin it is our belief that the statements indicate that a variety of undesirable influences will be introduced into this reservoir. The report is somewhat vague in discussing the overall long-term effect of these and indicates that constant monitoring will be done. We wonder if that monitoring shows permanent damage being inflicted, if it is feasible to believe that the project will be terminated once it is built. We find this almost an impossible assumption to accept.

2. One overall result of the environmental movement was to protect and preserve those present environmental resources that we have. It is implied in all environmental legislation that quality environments should be preserved and less than desirable environments should be upgraded to meet the optimum. The Draft Environmental Statement says that the Quabbin Reservoir will be degraded but, in the report's opinion, this degradation is not really that bad. On the contrary it is our belief that you are violating the intent of the environmental movement by lowering the quality of any existing resource.

A better approach, although admittedly more costly, would be to use the Merrimack River system or even the Charles River system, which is right in the receiver area, as the water supply. This in our opinion would accomplish two things. It would maintain the fine level of quality existing at the Quabbin and it would upgrade resources (Charles and Merrimack Rivers) that are now in deplorable condition. What you are doing by diverting the Connecticut River and Millers River watershed water into the Quabbin is just the opposite. You are degrading everything to a lower norm without improving anything.

3. In the discussions of the impact on the Connecticut River the statement is made many times that the sport fishery should not be harmed. Our review indicated that the sport fishery is used as the only criteria of environmental influence. The report appears to disregard negative influences that may occur on the non-sport fishery. We object to this type of reasoning because many species of the non-sport variety actually support, as part of the food chain, sport fisheries that you use as the overall criteria for judgement.

4. The report indicates that Tully Lake will be doubled to 600 acres and stripped of vegetation because it will be used as a domestic water supply. Does this mean that swimming will not be allowed? The water supply is not a final supply point, and, if this project comes to pass, we do believe that swimming should be a recreational use of that area. Our reasoning for this is that Franklin County is surface-water poor. A prime goal of the Franklin County Open Space study was to develop within reason and within environmental constraints as many surface water areas as possible to provide this needed recreational activity.

5. This agency was quite interested in the fine case that was made to indicate the negative impact on eastern Massachusetts if water were not diverted for its consumption. We were somewhat dismayed that a similar statement indicating the negative on western Massachusetts was not detailed. We feel that many of the statements describing dried lawns and reduction of industrial potential are also applicable in our area. For example, a report done by the engineering and consulting firm of Camp, Dresser and McKey for the Town of Orange states that Orange is now utilizing and consuming water at the safe yield of their water system and that future population demands will have to be satisfied with additional supplies. The question is: Why was the Town of Orange not included in the report? To pursue this further we wonder why there is no provision made for the donor communities to be provided access to the water system.

6. The Towns of Athol and Orange, the largest communities in the donor area, within the past year were declared economic development areas by the Economic Development Administration. This would indicate that the unemployment rate was high and that the overall welfare and economy of these communities is in serious trouble. If one makes the assumption that water supply is a resource which a community must have to promote future growth, we then ask the question: What is the overall, long-term impact by taking away this resource?

7. While this agency feels that surpluses should be shared, there must be mechanisms built into the system whereby those communities that now provide the surplus have the right to maintain free use of the resource when their own demands indicate a surplus no longer is real. The question we ask is: Why is there no mention in the Environmental Statement of a mechanism to allow the donor area to gain back the complete right of using the system?

8. Another environmental question which is not answered in the report is: Who pays? The MDC is a state agency and we wonder if the cost of this project will be allocated to the consumers or do all the residents of the Commonwealth pay for it? The report leads us to believe, through such a statement as "what happens in the eastern part of the state in terms of economic development has a total overall benefit in the state itself", that all citizens of Massachusetts will be assessed the cost of this project. This is an area which must be clarified.

9. If this project comes to pass one wonders of the trade-offs involved. As stated before, the Franklin County area sorely needs surface water for recreation purposes. Many of our residents look to the east and see the vast Quabbin Reservoir being used for one recreational activity--fishing. There has been much discussion in this area that this body of water be opened for boating and other uses. It is also the belief of many residents in this region that the Quabbin watersheds be used for recreation such as camping, picknicking and the like. The arguments we have received back from MDC is that the quality of the water is so fine that they would strongly object to uses that may infringe on that quality. The Environmental Statement indicates that that quality is going to be lowered. We wonder now if the recreational aspects we desire would not be compatible with the low quality water this project would introduce.

10. The Environmental Statement examines substantial ground water resource more closely adjacent to the receiver area, but indicates that they are too costly. We have no way of determining the basis of this statement since no costs are reproduced in the Environmental Impact Statement.

11. One graphic in the Appendix shows estimated demand on the Quabbin-Wachusett system. We are lead to believe that there is also an estimated demand for the Franklin County-western Worcester County area. We see no graphic for this. Does this imply that the Connecticut Valley Region is a static area and is undergoing zero growth? We think not. We then ask the question: What are the demands for the Connecticut Valley area and have they been taken into consideration on this proposed diversion?

12. We take strong objection to the statement that no irretrievable or irreversible committment of resources is taken. While in the strictest sense of the word, the rivers are still useable and good many structures associated with the project can be removed or hidden within the land, we wonder about the effects of digging a ten-foot diameter tunnel for over ten miles is going to have on the landscape. It is assumed that a variety of the material extracted from the tunnel will have to be disposed of. No mention is made of such disposition and its effects.

13. Many of the communities in the receiver area are experiencing rapid growth that they do not particularly desire. By adding additional resources upon which growth thrives it is quite possible that many of the community and regional plans now existing that guide growth will be undermined by providing the availability of an additional resource such as water. This directly affects Franklin County. Franklin County is slowly developing into a recreational area for those living in eastern Massachusetts. A recreational

industry is not wholly desirable and if the resources we (Franklin County) need to diversify our economy are taken away, it is highly likely that we will be forced into a single-entity economy and become subjected to severe economic fluctuations. Adding a great deal of population to eastern Massachusetts will, no doubt, further this region into becoming a recreation area. Removing a resource, such as water, will further guide us into a single economic system. We feel this is undesirable.

In summary it is our belief that the social, economic and biological impacts that make up a total environmental statement have not been produced in this document. We feel that these impacts as they relate to eastern Massachusetts have been well covered, but as they relate to the donor area the coverage is wholly inadequate. It is our final recommendation that the project not proceed further until the donor areas concerns are answered.

Sincerely,

Frederick J. Muehl
Planning Director

FJM:brh

December 27, 1972

s is to certify that at a meeting of the Court of Common Council of City of Hartford, December 26, 1972, the following RESOLUTION was passed.

WHEREAS, The Commonwealth of Massachusetts has adopted legislation authorizing the Boston Metropolitan District Commission to divert Connecticut River water through the Northfield Mountain pumped storage project into Quabbin Reservoir for distribution and consumption in the Boston Metropolitan Area; and

WHEREAS, The Commission is already proceeding with construction of aqueducts and other works preparatory to such diversion; and

WHEREAS, The Commission is also advancing plans for diversion of water from the Miller's River Watershed, which is tributary to the Connecticut River, into Quabbin Reservoir and Metropolitan Boston supply; and

WHEREAS, The Preliminary Draft of the Environmental Statement relative to both the Northfield Mountain and Miller's River Basin diversion projects prepared by the Department of the Army, New England Division, Corps of Engineers and issued in November 1972 constitutes, in effect, an endorsement of these diversions; and

WHEREAS, Said Statement does not adequately take into account the implications of the proposed diversions as these may affect the future water supply needs and choices of downstream areas and communities, including Hartford, and is especially deficient in its failure to note the basic incompatability of unilateral action by a single state with the principle of sound environmental planning and management in a multi-state and multi-basin area; and

WHEREAS, Criticisms of the Statement have also been made by responsible organizations and agencies, including the State Department of Environmental Protection, as to the adequacy of analysis of the long-term ecological effects of the proposed diversions, in the light of requirements of Connecticut River flow for

restoration and maintenance of environmental health in flood plains, wetlands, estuary areas and Long Island Sound; and

WHEREAS, The City of Hartford has a vital stake in the protection and improvement of the Connecticut River as an environmental, recreational, economic and potential water supply asset to the City and region, and therefore has a vital stake in all aspects of the issues involved in the proposed diversions; now, therefore, be it

RESOLVED, That the City of Hartford hereby responds to the Preliminary Draft Environmental Statement relative to the Northfield Mountain and Miller's River Basin Water Supply Projects by recording itself in opposition to these proposed diversions at least until such time as the riparian rights of the City have been recognized and provided for through adequate institutional arrangements representing jurisdictions having rights and interests, and also until the implications of the proposed diversions with respect to ecological effects and future water supply needs in areas downstream have been more adequately studied and considered; and, be it further

RESOLVED, That the City Manager and Corporation Counsel be and are hereby authorized to take such further action as necessary or appropriate for protection of the City's interests with respect to the proposed diversions.

Attest:

Robert J. Galliran

Robert J. Galliran
City Clerk

TOWN OF MONTAGUE

Office of the Selectmen

1 AVENUE A
TURNERS FALLS, MASS. 01376

Donald H. Skole, Chr.
Joseph E. H. Bonnette
Henry G. Waldlich

Helen E. Muszynski, Cl

December 26, 1972

Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Mass., 02154

NEDED-R

John Wm Leslie
Chief, Engineering Division

Dear Sir:

This letter is in response to the Preliminary Draft Environmental Statement for the Northfield Mountain and Millers River Basin Diversion proposals of the Northeast Water Supply Study. My comments will be directed primarily toward the Millers River Basin portion of the report.

In view of the very limited research and data on the effects of interbasin transfer of river waters, it is my recommendation that implementation of major diversions like the Northfield Mountain and Millers River be postponed until such time that significant pilot project data are available for evaluation.

Most inappropriate is the diversion of water from the tributaries of the Millers River. It is my feeling that no water project be pursued that would adversely affect the over-all water quality of a region. Diversion from the Tully Flood Control Dam and/or the Tully complex would seriously deteriorate the quality of the main stem of the Millers River by decreasing the dissolved oxygen content and increasing the proportion of pollutants. This deterioration would extend into the Connecticut River Basin.

In the area of land acquisition and use for diversion purposes, the role of the Metropolitan District Commission (MDC) should be most specifically defined following cooperative agreements between that agency and the communities and individuals involved. Current MDC policy with regard to public access and use of the Quabbin region is arbitrary and denies any public participation of development of land and water use policy, particularly in terms of recreation.

In my opinion, a sound approach to a Millers River diversion would place emphasis and priority on the restoration of high quality water to the main stem of the river, and that actual diversion be restricted to the main stem of the stream, and that such diversion would not be implemented until an acceptable agreement had been reached between the communities of the basin, the Army Corps of Engineers, and the MDC in terms of time and volume of diversion and any other conditions that the participants deemed necessary.

Your consideration of the forgoing recommendations and views would be deeply appreciated.

Sincerely,

Henry G. Waidlich

Henry G. Waidlich
Selectman
Town of Montague

Natick Conservation Commission
24 MAIN STREET - P. O. BOX 233
NATICK, MASSACHUSETTS 01760

January 10, 1973

Mr. John W. Leslie
Chief, Engineering Division
Department of Army, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

The Natick Conservation Commission has reviewed the Preliminary Draft Statement for: The Northfield Mountain and Millers River Basin Diversion proposals of the Northeast Water Supply Study and found that it has some very basic faults.

In general, the proposed diversions will do the short-term and business-as-usual engineering job of increasing the supply of water to the Quabbin system, but the report does not offer alternative actions for resolving the real problems of water resource supply and demand. In fact, this report dismisses many pragmatic alternatives and thus is unacceptable.

For the long-term benefit for the entire Commonwealth of Massachusetts, this report and NEWS study should work for implementation of one or more of the following alternatives:

1. Waste-water reuse.
2. Local ground and surface water resource development.
3. Local water pollution treatment.
4. Water rate changes - water should not be subsidized, it should pay for itself, and over-use should be prevented.
5. Programs to modify domestic plumbing in its over-use of water.
6. The MDC should be given legislative permission to increase its rate charge.
7. A concentrated effort to clean up and use the Sudbury and Cochituate reservoirs and the Merrimack Rivers for water supply should be implemented.

Numbers one through five apply to both the receiver and donor areas as the terms are used in the NEWS draft statement with the overwhelming emphasis on the receiver areas.

The basis for our reasoning is that Natick is projected to be one of those towns that will have to join the Quabbin system by 1990. The graph on Page 63 of the report indicates that even with all the proposed diversions operative, the system will be empty by 2003±. Thus it is only common sense that new alternatives for water supply and demand are needed, rather than diversions.

We in the eastern part of the state can no longer take it for granted that we can overdevelop, over-populate, etc. and obtain the resources to do so from the "less-developed" western part of the state. Such actions only place us BOTH in greater dilemnas in the future.

Sincerely yours,

George H. Wallace

George H. Wallace, Chairman
NATICK CONSERVATION COMMISSION

GHW/mg
cc:Senator Edward M. Kennedy
Senator Edward Brooke
Congresswoman Margaret Heckler
Congressman Robert Drinan

CONNECTICUT AUDUBON COUNCIL, INC.

HEADQUARTERS: ORCHARD HILL ROAD
HARWINTON, CONNECTICUT 06790
TELEPHONE: 203 - 482 - 4173

December 27, 1972

John WM. Leslie
Chief, Engineering Division
Department of the Army
424 Trapelo Road
Watham, Massachusetts 02154

Dear Sir:

The Connecticut Audubon Council has reviewed the Preliminary Draft Environmental Statement for: The Northfield Mountain and Miller River Basin Division proposals of the Northeast Water Supply Study, as requested in your letter of 13 November 1972.

Attached is a copy of our comments and recommendation. It is our opinion that the report should be revised to consider in detail the comments noted. Until this is done, the report is considered unacceptable by the Connecticut Audubon Council.

Sincerely yours,

George Letis
George Letis
President C. A. C.

Attachments: Comments (1 copy)

12/26/72

Subject: Preliminary Draft of The Northfield Mountain and Miller River Basin Division proposal of the Northeastern United States Water Supply Study Southeastern New England Study - November 1972

The subject report has been reviewed and the following comments are offered.

Overall, the report's recommendation based on the data presented appears to be the optimum short term solution for the Boston area requiring additional water. The report places considerable emphasis on:

a. Availability of existing potential supply sources.

b. Water quality of these sources.

c. Impact on the storage area (reservoir).

d. Cost factor to utilize these sources.

However it does not:

1. Consider in any significant detail the environmental impact of water diversion on the areas affected i.e. the Connecticut River Valley.

2. Define how existing water overflow will be adequate for the use intended, and if not, then what?

3. Define the full extent of private utility involvement.

4. Give serious consideration to other viable solutions; such as reclaiming sea water which offers both a short and long term solution to the problem.

In summary the report supports the recommended solution for supplying water to the Boston Metropolitan District. However, it does not fully consider all the environmental impact of the selection, nor does it seriously consider other options which would have less environmental impact, or higher initial costs. It is recommended that this report be considered unacceptable by the Connecticut Audubon Council as written.

G. N. Kleiner, P. E.
(Treasurer C. A. C.)

CONNECTICUT FOREST AND PARK ASSOCIATION INC.
1010 Main Street P.O. Box 389 East Hartford, Conn. 06108 Telephone (203) 289-3637

Founded 1895

COMMENTS SUBMITTED BY THE CONNECTICUT FOREST AND PARK ASSOCIATION, INCORPORATED, FOR THE PRELIMINARY DRAFT, ENVIRONMENTAL STATEMENT, NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT, MILLER'S RIVER BASIN WATER SUPPLY PROJECT, NORTHEAST WATER SUPPLY STUDY (NEWS), Prepared by U. S. Army Engineer Division, New England, Waltham, Massachusetts, November 1972.

The Connecticut Forest and Park Association, Incorporated has maintained an interest in proposals for diversions of water from the Connecticut River and its tributaries to eastern Massachusetts for the past several years. At the outset, we wish to note that our interest rests primarily in the area of representing downstream interests with a future stake in the water resource of river.

We recognize that the diversions called for in the study have been in the planning stage for some time, particularly the Northfield Mountain Water Supply Project. We wish to indicate that the draft statement fails to recognize the need for a more detailed analysis and evaluation of these and other diversions within and without the watershed of the Connecticut River.

We feel that the need to plan and develop institutional arrangements for the allocation of water resources in relation to the proposed and other diversions of the Connecticut River has been completely overlooked. This need was underscored by the Citizens Review Committee on the Connecticut River Comprehensive Water and Related Land Resources Investigation as recently as 1971 and it is difficult to comprehend why it is ignored as a matter of prime importance in 1972.

We have concerns relative to the possibility of the diversions at Northfield and the Miller's River Basin Water Supply Project being viewed by the Metropolitan District Commission as a justification for additional diversions from these and other tributaries of the Connecticut to meet other needs within the service area of the Commission beyond 1998.

The most alarming fact that the statement brings out is that Quabbin will be a dry reservoir in 1985 if these projects are not allowed to progress. The fact that Quabbin will not be a viable supply system prior to 1985 because of the deterioration of the water quality is also disconcerting. These facts once again illustrate the results of inadequate planning on the part of the MDC to meet future needs. The problems of the blind assumption that all of the needs of the MDC service area can be met without

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substantial changes in water consumption habits and use and that there are no limits of the ability of the Connecticut River and its tributaries are also underscored.

We do not wish to imply that we want to deny the MDC service area of a supply of water from the Connecticut River and its tributaries to meet short and mid-term needs. The Northfield Mountain Project in itself, however, can serve to meet these needs. We feel that there are still many unanswered questions on the impact of the Northfield Mountain Diversion on Quabbin and still more on the Miller's River project. In addition it appears that there may be questions on the methods devised to allocate the Miller's diversion. We are not in a position to comment on the technical details of these problems. We feel that they need to be more fully explored before the Miller's project is approved.

We have given some careful consideration to alternatives presented in the draft statement and we feel that a disproportionate emphasis has been placed on the negative aspects of no diversion. The positive alternatives of placing reasonable limits on consumption and moving toward re-use of water in the industrial sector are de-emphasized. We do feel that weather modification is not a reasonable alternative for consideration at the present time. We feel that diversions from other locations on the Connecticut pose the same problems as the ones considered and as down stream interests result in the same problems developing at various points in time.

The examination and analysis of potential ground water supplies in Plymouth County appear to be incomplete. Economic and social costs are referred to but they are not completely analyzed. In this aspect the statement does not appear to recognize the fact that over time, water as a resource will of necessity become more expensive.

In general the comments regarding future costs relative to the review of desalination as an alternative source of water at some point in time in the future are treated in the same manner.

It would be desirable to explore more fully the Sudbury as a source of water. The need for demographic and land use policies that will reduce the commitment of resources external to the MDC service and to meet needs within this area is inadequately recognized.

In conclusion we have to take exception to the treatment of the waters being considered in the Northfield and Miller's Rivers Projects as being state (Massachusetts) resources. The statement appearing on page 156 of the draft, "It should be pointed out that both donor and receiver areas are within the borders of Massachusetts, so that economic benefits realized by the construction of the project would be reflected favorably on the state's economy as a whole." is fallacious. While it is true that the projects are within Massachusetts, the water resource has to be considered as a regional resource.

It is the feeling of the Connecticut Forest and Park Association, Inc. that the factors which make consideration of both the Northfield Mountain Water Supply Project and the Miller's River Basin Water Supply Project necessary in 1972 re-emphasize the immediate need for the development of institutions and mechanisms to allocate the water resources of the watershed of the Connecticut River on a regional basis. The corresponding need of the Metropolitan District of Boston to plan more adequately for meeting the needs for water resources with a more detailed examination of all alternative sources in the years ahead is once again underlined.

We appreciate the opportunity to present these comments and request that they receive careful consideration in the preperation of the final environmental statement.

Respectfully submitted,

John E. Hibbard

John E. Hibbard, Secretary

CONNECTICUT RIVER WATERSHED COUNCIL, INC.
125 Combs Road Easthampton, Mass. 01027 Telephone (413) 584-0057

December 13, 1972

John Wm. Leslie, Chief
Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Re: Preliminary Draft Environmental Statement
Northfield Mountain and Miller's River Basin Water Supply Projects

Dear Mr. Leslie:

The Connecticut River Watershed Council, Inc. has participated in early discussions and formal public hearings relative to both the above out-of-basin transfers of water from the Connecticut River valley. We have submitted formal statements on these proposals to appropriate state and federal agencies and the Boston Metropolitan District Commission, and including the General Court of the Commonwealth beginning in 1969. We would call your attention specifically to our statements filed with Colonel Frank P. Bane dated February 11, 1970 and July 6, 1972 which are concerned, either in part or in whole, with the diversions of water either from Northfield Mt. or the Miller's River.

We have repeatedly raised questions which represent the concerns of our valley's residents during public hearings on these projects. Moreover, we have requested the U. S. Army Corps of Engineers, or the Boston Metropolitan District Commission, to provide answers to and action on those matters of concern expressed in our submitted statements. The fact that no attention to the views and concerns of the valley citizens is evident either at hearings, follow-up correspondence, or in succeeding published reports is indicative of the lack of concern your agency has for public response.

The current draft environmental Statement is further testimony of the U. S. Army Corps' disinterest in responding to private citizens' and organizations' views which have been expressed repeatedly at earlier meetings and public hearings. The Statement also substantiates the tenor of the federal General Accounting Office's recent report which criticizes the Corps of Engineers, among others, for not disclosing fully all adverse environmental effects of their projects; by complying with the 1969 law on national environmental policy in form but not in substance, and that, in general, the quality of the impact statements is poor.

In this respect, we wish to submit the following comments and to raise again several specific concerns as our response to the Draft Environmental Statement.

(1) We believe the entire diversion projects have been based upon an unacceptable premise - which is they are predicated upon a control flow of a minimum of 17,000 cfs in the Connecticut River at Montague City U. S. Geological Survey

gaging station. This control flow was elected not from any environmental determination but rather from Massachusetts State Legislation (relative to the Northfield Mountain Project) which was based solely upon the hydro-power generation needs at Turner's Falls dam. The 17,000 cfs flow, which includes the peak average annual flow of the Deerfield River, is principally the storage head needed at Turner's Falls to develop hydro-power at the Cabot station.

To use the needed make-up water for power generation as the desirable minimum flow for diversion purposes, is certainly not responsible environmental determination. This is particularly undesirable in consideration of the Miller's River diversion which is also set for the same stage flows at the Montague gaging station.

As increased water flows are being considered by the Federal Power Commission in relicensing of Turner's Falls and the four immediate upstream dams (currently an additional .20 cfs per square mile of drainage), it would be consistent in the Corps of Engineers' thinking to make these additional flows available for diversion under the current method of streamflow calculation - although, in fact, these increased flows are for the enhancement of anadromous and resident fish species and recreation in the Connecticut River.

Therefore, we believe that another premise must be found upon which to determine possible environmental impact of water diversions rather than that based upon hydro-electric power needs.

(2) Our Council has questioned many times the statements made by responsible state and federal agencies that there exists a 'substantial surplus of water' in the Connecticut valley that will not be needed for valley use. Never has this been substantiated in reports issued by the Corps of Engineers.

We do not believe that the availability of water (surface and ground supplies) and the future demands for water supply in the Connecticut River valley have been fully studied or planned for. Until these are ascertained, no judgement of value can be made as to the effects of water diversions on the donor area.

We suspect that the lack of consideration given in this Statement to the environmental impact of diversions on the donor area is a direct result of not having this basic and critical information available.

(3) It can also be assumed that identical impacts may occur within the donor area if diversions are allowed as has been suggested to occur in the receiver area if diversions are not allowed. It is likely that as additional water supplies are needed in the valley - both in Massachusetts and Connecticut - that a 'prior appropriation' of these waters outside the valley will result in a slow-down in this valley's socio-economic development, municipal services, employment, recreation opportunities, and frustration of citizens as "they see their lawns dry up during watering bans".

(4) Since 1970, the Council has consistently asked the following questions with no answers having been given. We ask these again:

a). What legal commitments are to be provided by the MDC for returning proposed diversion waters when they are needed by riparian communities, landowners, and industries within the valley in Massachusetts and Connecticut?

b). What compensation, or equities, will be established with riparian communities, landowners, and industries for the withdrawal of their riparian waters' We see no "quid pro quo".

c). What assurances are being provided that present proposed diversion levels will not be exceeded after 1990, or before?

We believe that these questions should be answered now by the Boston Metropolitan District Commission and made part of the final environmental statement report.

(5) The report dismisses the development of the substantial (300 mgd) groundwater resources in Plymouth County as being more costly than Northfield and the Miller's projects combined - yet, we have no costs to compare for any of the projects.

Although the report gives scant reasons for dismissing further consideration of groundwater as an alternative, we disagree with those given, and urge that more in-depth, impartial, evaluation be given to this alternative.

(6) Except for a 2½ page description of facilities, there is no impact evaluation of the actual construction of the various aqueduct tunnels. CRMC has already experienced that such activity is detrimental, based on M.D.C. field investigation activities in the Wendell section of the Northfield-Quabbin line and in particular at our Whetstone Wood Sanctuary in that town.

Privately, M. D. C. officials have suggested that there is a possibility of "temporary" disruption of private wells (ground water) as a result of the tunnel itself. Further, the so-called construction shafts will require a surrounding land area for support facilities and to provide a place to stock pile waste rock from the tunnel. Such sites will doubtless be areas of intense heavy equipment activity. Trucks and machinery will be active in and about these sites, and the impact will be felt in the forms of additional noise and air pollution in the area, as well as adverse impact on existing light duty road facilities which could be degraded by heavy trucking.

The volume of rock resulting from a tunnel 9.8 miles long, 10 feet in diameter, is considerable, yet no mention is made as to where this material is to be placed. The final permanent location of the spoil rock should certainly be discussed in the impact statement.

(7) Before large water diversion projects with substantial long term capital investments are constructed in this valley, we submit that much more study and evaluation of alternative water supply sources in eastern Massachusetts needs to be done. And, we believe that further environmental impact studies are needed on the donor area in the instance of the Northfield-Miller's River proposals.

We believe this response to the November, 1972 Draft Environmental Statement is clear, and that the time is at hand to have questions answered. We respect your decision that our response will be included as part of the Final Statement.

Respectfully submitted,

John C. Calhoun, Jr.

John C. Calhoun, Jr.
President

LOWER PIONEER VALLEY REGIONAL PLANNING COMMISSION

1499 Memorial Ave., West Springfield, Massachusetts 01089, Tel. 413-739-5383

K. M. MUNNICH
Planning Director

December 26, 1972

Mr. John W. Leslie, Chief
Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

RE: Preliminary draft environmental statement Northfield Mountain and Miller's River Basin water supply projects

Dear Mr. Leslie:

The Lower Pioneer Valley Regional Planning Commission has received the above document, dated November 1972, and has reviewed its implications for the environment of this planning district. We would like to submit the following comments for your consideration.

1. The chief direct effect of the diversion proposal on this planning region would be a reduction in flow of the Connecticut River. While the resultant possibility of ecological harm and reduction of river water quality might appear limited at this time, study in greater detail would be needed to more firmly establish this view. It can be said that the use of the minimum control flow of 17,000 cfs as a basis for water diversion to Quabbin Reservoir is a questionable standard, in light of its basis in power generation needs rather than environmental criteria.

2. We are concerned as to how water diversions would be monitored. We submit that upstream and downstream continuous gauging would be needed to guarantee that the terms of the diversion proposals are met.

   We note that no specific flows are proposed for Alternatives 1 and 3 of the Miller's River proposals. Concerning control flow values given for Alternative 2, should not the August, September, and October control flow be maintained at no lower level than that proposed for July?

   Socio-economic effects of the diversion proposals are considered in the draft statement to be positive for the water supplier area, i.e., the Connecticut River valley, in terms of a healthier overall economy for Massachusetts, a "healthier" and more esthetic Quabbin

Reservoir, creation of construction jobs, and the cleanup of the Connecticut River tributaries. Against these, however, must be weighed the basic fact that the diverted waters will no longer be available for use by the communities of the donor area. The curtailment of development of water supply systems based on the Connecticut River watershed by valley municipalities may result in socio-economic problems for this region comparable to those the impact statement claims would face the Boston Metropolitan District.

4. No clarification is given as to the types and amounts of compensation that would be offered the riparian communities and others for the withdrawal of riparian waters.

5. The Commission is of the opinion that the development of alternate water supply sources in eastern Massachusetts needs more close consideration. The development of groundwater supplies appears as one promising example. The draft environmental statement states that groundwater development in the Plymouth County area "could offer a viable alternative source of water supply for eastern Massachusetts (p. 131)." No estimates of costs, however, are given for this alternative. We note on page 133 that the Northfield Mountain diversion will cost $550,000 per mgd; this would appear to be much higher than groundwater development costs for many areas.

   In the discussion of desalinization (pp. 118-123), a cost comparison between this method and diverted water gives the value of 14 cents/1000 gallons for the latter. No data is presented as to how this figure was derived. Are both capital and operating costs included? What is the present cost of MDC water? The comparison of 73 cents/1000 gallons for desalinated water against 14 cents/1000 gallons for Miller's/Northfield diverted water should be documented further.

   Much discussion is given on the effects of pricing to reduce water demands (pp. 142-149). The general conclusion is that residential demands are not significantly affected by increasing water costs. For industrial users the picture is not as clear. We suggest that a graduated water pricing system could have significant effects on demand, especially for industrial users; i.e., through increased use of recycling.

6. We are concerned with the lack of reference in this draft environmental statement to the major study done recently on the Connecticut River basin, that is, the Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin (June 1970), in which the Corps of Engineers had a major role. While the relationship of the present diversion study to NEWS and the Southeastern New England Study is discussed, there is no indication of how the diversion proposals fit in with this important study of the Connecticut River basin itself. Presenting the current diversion proposals as vital components of a comprehensive plan for the Connecticut River valley is a fundamental need that appears unsatisfied. Agencies involved in such individual diversion projects should consider them as but parts of the total picture.

We trust the above comments will be of assistance to you and will be included in the final environmental statement.

Very truly yours,

K.M. Munnich
Planning Director

KMM AMB mck

cc: Environmental Impact Evaluation Advisory Committee(7)
Franklin County Planning Office
Montachusett Regional Planning Commission
Central Massachusetts Regional Planning Commission
Capital Region Planning Agency
Connecticut River Watershed Council
Connecticut River Basin Program
Office of State Planning and Management
Curran Associates

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December 27, 1972

Comments on Preliminary Draft of
Environmental Statement on the Northfield
Mountain and Miller's River Basin Water
Supply Projects (NEWS)

I. INTRODUCTION

As active environmental advocates, we applaud the Army Corps of Engineers for the effort which it is putting into an assessment of the likely impacts of the proposed diversions of Connecticut River water to metropolitan Boston via the Quabbin Reservoir before a commitment is made to proceed or not to proceed with the project. The water supply question is a critical one and is tied up with larger issues of land use and long-range planning with which government is just beginning to wrestle. Like the transportation decisions which Massachusetts' Governor Francis Sargent recently made, the water supply decisions will have major and long-lasting effects on both the metropolitan Boston area and on other parts of the Commonwealth. As environmentalists, we hope to see the same willingness to take a fresh look at the diversion projects that we saw for the metropolitan Boston highway decisions.

Unfortunately, we find substantial deviations from realistic appraisals in this preliminary report concerning the probable impacts of the proposed diversion project.

The most critical issue of diversion is not treated in any substantial way by the statement. That issue is implicit in the graph (page 63) which shows Quabbin empty by 2003+, regardless of the currently proposed diversions. In historical retrospect, it was promised when Quabbin was proposed, that the facility would supply Boston for 137 years (Ware River News, Aug. 8, 1895, p.1). Instead, the presence of an abundant supply of water from Quabbin has been one of the factors resulting in a stimulation of growth, resulting in Boston's overtaking its water supply resource in considerably less than the estimated period. There is no program set forth in this preliminary draft impact statement that would prevent the same thing from happening to the increased water supply that would be realized by the proposed diversions.

Alternatives will have to be found and in a short interval in terms of the time frames of technological and political development. It seems from our viewpoint that those alternatives would probably be desalination, waste water recycling, local pollution treatment, groundwater resource development, increased user charges, more sophisticated systems of domestic plumbing and groundwater recharge.

None of these alternatives is adequately discussed in this report. This is evidenced by the paucity of detail provided for the "alternatives" - a deficiency which must be remedied before this preliminary draft environmental statement will provide the necessary information to allow the decision to build or not to build the proposed diversions to be made rationally. Concerned environmentalists are alarmed by the report's failure to advocate by an integrated program of water supply expansion and demand limitation, the means to a long-term solution.

II. THE PRESENTATION OF ALTERNATIVES

It is our opinion that this report was written to justify a preconceived solution to the water supply problem rather than to explore and evaluate alternatives in a fair manner. As evidence of this bias we cite the following:

A. The presentation of detail for non-diversion alternatives is very sketchy, and when alternatives are presented, the detail is presented very selectively. For example:

1. In assessing the feasibility of re-developing the old MDC system on the Sudbury River (potential 40 million gallons per day), the report cites (p.136) the preliminary cost estimate of $43 million for water treatment facilities to improve water quality with no mention of the benefits of instituting such a clean-up. By contrast, no cost estimates are presented for any of the treatment facilities that would be required to abate pollution from industrial and municipal sources upstream of the proposed diversions on the Millers (p.16) and Connecticut Rivers; however, the benefits of such a clean-up are clearly associated with implementation of the proposed diversions. "The facilities to insure use of the river as a water supply source would provide an excellent quality water in the river. A clean Millers River would open up important new recreation and land use opportunities, not now enjoyed because of the polluted nature of the river." (p. 18, similar claims on p.24,p.25.) On p. 109, "a cleaner river" and "larger, more lasting effects on the regional economy occasioned by the waste treatment plant construction and operation" would be insured by Alternatives 1 and 2 (Millers and Tully-Millers diversions). It is grossly misleading to list benefits and no costs for the desired alternatives and costs but no benefits for the non-preferred alternatives.

2. "Socio-economic impacts" are similarly used in the report to favor the structural approach to water supply and to damn non-structural approaches. Witness the analysis of the "no-go" solution (p. 106): "There is no way of knowing, for instance, whether it would be municipal expenditures on recreation or on schools or on some other category that might suffer. Therefore, an estimate of the loss in classrooms not built (say 600 rooms) is merely one possible expression of total dollar loss..." Such conjecture is sensationalistic, offensive, and totally inappropriate to a rational consideration of the alternative approaches. By contrast, the impacts of the "go" alternative are described as "relatively small". (p. 109) "Objectively speaking, little real proof of harm can be demonstrated by even the most adamant opponents of implementation." This is rhetoric, not analysis.

3. No mention is made of the projected cost of water obtained from ground water sources in Plymouth County. The report states: "On the basis of (cost) estimates, it was determined that such a ground water resource alternative would be much more costly than Northfield Mountain plus any one of the Millers River basin alternatives." (p. 131) Yet no cost per 1000 gallons figure is presented for comparison with diversion water, desalination, and other alternative sources, despite the fact that this source has, an estimated safe yield of 300 mgd , more than twice the increase in demand projected to occur from 1970 to 1990.

4. We can find no evidence in the draft preliminary statement that ground-water recharge, wastewater reuse, and conservation of water by eliminating leaks in the MDC system and in the systems of user communities were seriously investigated. The draft statement, when it deals with these alternatives at all, concentrates on the problems associated with them and minimizes the advantages.

B. The preliminary draft statement demonstrates a remarkably discretionary use of caution . In general, uncertainties with the alternative, non-diversion alternatives are grounds for rejecting the alternative, while even greater uncertainties with the preferred diversions proposals are dismissed. For example:

With respect to desalination, "aside from the economic costs....potential hazards to the environment .... might occur from disposal of waste brine. ... As a result, this report concludes that desalination not be considered at this time as a viable alternative source of water in eastern Massachusetts for the short-range water supply problems." (p. 123)

With respect to waste water reuse as a municipal supply, "use of renovated waste water as a regular domestic supply, however, requires full results of proposed research. Until such research is completed, waste water reuse as a municipal water supply is not a viable alternative to meet short-range supply needs." (p. 128)

With respect to water demand control, "use of increased water supply prices as a method to conserve a resource may have merit. Yet to be determined, however, are data to support the theoretical impact such increases would have upon the demand within New England. Also unknown with this approach are the social and environmental costs which would be borne by the consumer. It appears then that much work remains to be done on this approach such that it can be evaluated as a viable alternative to increased supply." (p. 149)

By contrast, the report states:

"A number of questions still remain, however, on the water quality of the Millers River even after "clean up." [namely, existing sludge and non-point pollution sources] (p.16-17) "Apparently, then, if this alternative were chosen, no guarantee can be given that the water, when needed would be available." (p. 18)

"As in Alternative No. 1, the impact of diverted Millers River water on Quabbin Reservoir is impossible to discuss, but in very general terms." (p.23)

"There can be little doubt that increased levels of nutrient chemicals will be detected in Quabbin Reservoir after the implementation of the Connecticut River diversion via Northfield Mountain." (p. 38)

Table 1 (p. 58) indicates the probability of "introduction of undesirable species "to Quabbin would be "high" for Connecticut River diversion. "The number of angling trips to Quabbin may very well decline." (p. 42)

Yet, faced with these (and other) questions and probably (but not certain) environmental impacts, the "summary sheet" can proclaim: "No significant changes are predicted for Quabbin Reservoir." There is a rather clear intent on the part of the authors of this preliminary draft statement to justify one or more of the diversions alternatives discussed in the first 110 pages of the report and to discredit non-diversion alternatives.

One of the clearest examples of the report's discretionary exercise of caution concerns the possibility of viral contamination of water supply from fecal sources. The authors chose to place the summary of a paper, by Lang and Bell from the Journal of the American Water Works Association, which details the need for studies of viral contamination of public water supply in the consideration of waste water reuse. In fact, presentation of this material occupies fully 70% of the three pages devoted to this non-structural alternative solution, whereupon waste water reuse is rejected "until such research is completed". (p. 128) The authors of the report chose not to place this material in the discussion of the public health aspects of diversion alternatives which begins on page 43, despite the presence of treated and untreated municipal and industrial waste sources upstream of proposed diversion points on both the Connecticut and Millers Rivers (p.30,p.15) Moreover, "it is reasonable to assume that concentration of coliforms will increase in Quabbin Reservoir as a direct result of the Connecticut River diversion", (p.43) and "the possibility that some pathogens may find their way into the Quabbin aqueduct has to be assumed." (p.45) Even accepting the report's analysis of the "treatment plant" capacity of Quabbin Reservoir, we have difficulty accepting the editorial decision to raise the viral contamination issue more strongly in the context of wastewater reuse than in the case of diversion.

III. THE ECOLOGICAL ANALYSIS

We find that we often do not share with the authors of the preliminary draft environmental statement the same perceptions of the ecological and related issues that are presented in their report.

A. There is an inaccurate understanding of the riverine ecosystem and the ways in which its various elements interact. The donor areas involved in the proposed diversions are not treated as systems. The report does not attempt to analyze food chains to determine the importance of what might appear minor organisms to the sustenance of other biota.

1. For example, we have difficulty with the statement that "wetlands by their definition are wet all year round so that no impact would be expected on them." (p. 51) This view ignores completely the important interaction between the flood and that portion of the flood plain which is not permanently wet. A reasonable assessment of the impact of the diversion on intermittent wetlands would be necessary in an honest statement. Indeed, the impact of this diversion must be added to flood

stage reduction by the existing system of flood-control structures. It is this total impact on the estuary, floodplains, marshes, swamps, bogs, forests and such wildlife as anadromous fish and oyster drills which should be evaluated before further manipulation of the flooding event is undertaken.

2. The statement: "The fish population, while composed of many species, contains only a few which can be regarded as being important to anglers." (p.37) illustrates a tendency to consider the impact on non-game aquatic species as insignificant. Such statements invite the angler and the public to forget that no organism exists in a vacuum, that each of these species is part of a complex food web. So, in reality, the interrelated assemblage of populations of such species of fish and the ecosystem which supports them must be considered.

3. The analysis of river morphology in the estuary (p.96-104) concentrates entirely on the question of how far the salt water/freshwater interface during freshet conditions is likely to migrate upstream as a result of reduced freshet flow. The draft statement fails to describe any analysis of the impact anticipated in coastal marsh areas at the mouth of the estuary which, because of reduced freshet flow, fail to experience the reduction of salinity which is natural at freshet time.

4. Systems analysis must replace guesswork and crude subjective evaluations in justifying assumptions and pursuant actions. Systems analysis will probably not turn out, in the long run, to provide the whole answer to living within the ecosystem, but it is certainly the next step within our reach. It is being ignored in a conspicuous way by those seeking mechanical solutions to ecological problems.

5. There is a tendency in the report to downgrade or neglect ecological disbenefits of the proposed diversions. For example, to the extent that flood water skimming will interfere with the annual cycle of renewal of agricultural lands that lie in the floodplain of the Connecticut River, the cost of the additional fertilizer that farmers downstream of the diversions must use to compensate for the loss of the annual spring flood soil enrichment should be included in the costs of the diversion. In similar ways, a number of the environmental costs which would occur if the diversions take place - loss of biological productivity in the estuary, damage to the Quabbin fishery by introduction of exotic species, loss of recreational canoeing opportunities, etc. - can be estimated and incorporated into the cost of the project.

B. There is a substantial failure in the report to consider the cumulative effect on Connecticut River flood stage of the proposed diversions combined with existing diversions and flood-control reductions. The report dismisses as insignificant the 1-2% reduction in the natural downstream flow in the Connecticut River during the spring runoff diversion period (p.38) that would result from the Northfield Mountain diversion. The Northfield diversion, which would amount to 26.3 billion gallons per year (average), however, would be an addition to theexisting Quabbin watershed (85 billion gallons per year) and Ware River (11 bgy) diversions. (Table 3, p. 64) If, in addition, the Tully System diversion (17,5 bgy) were added, one begins to get a more accurate picture of the total, cumulative impact. The intention to consider

the Northfield and Millers-Tully diversions as phase I and II of a future diversion program - not as true "alternatives" - is certainly implied by Figure 1 (p. 63) and associated text. There is, furthermore, considerable uncertainty in how many other diversions might be in prospect for the future (viz. "during the first few diversions" and "for operational guidance in future diversions" on p. 42). Thus, it is important that the proposed projects be treated as additions to the existing Quabbin diversion, and that the impact of the whole out-of-basin transfer be analyzed. It is in this context that the questions raised by Dr. Bernard Berger in his paper "Social and Ecologic Implications for Out-of-basin River Diversions" should be definitively answered before the proposals are undertaken.

C. On a broader, more philosophical level, we have considerable difficulty accepting the attitude which is apparent in the discussion on "Socio-Economic Impacts of all Diversion Projects" which begins on 105. The authors of the preliminary statement seem to be operating on the implicit assumption that all economic growth is good. "The net result (of a no-diversion decision) is stagnating growth, hostility toward the communities which snare the industries unable to locate in a water-deprived town, and a growing dependence on MDC admission as the ultimate solution to water shortage." Without accepting the validity of this analysis, we challenge the assumption that economic growth in the recipient area must be accommodated and that if it is not accommodated by diversion there will be enormous "socio-economic" losses.

We challenge the notion that loss of municipal revenue (p. 106, p. 114) (presumably because the community water supply system delivers less water) is a valid measure of economic loss. This would be true only if the community is able to operate its water supply system at a net profit.

We challenge the notion that a decision not to implement the proposed diversions would increase dependence on the MDC system. To the contrary, by undertaking a balanced program to conserve water, protect and develop local ground and surface water sources, and reuse waste water, we would lessen dependence on Quabbin and get the MDC off of the endless treadmill of seeking additional new sources to meet an ever-expanding demand. The diversified approach is, in ecological terms, much more desirable because it is far less subject to disruption.

It is becoming widely recognized that all economic and political sectors must begin to live within their means. While it is obvious that no region can produce all the necessities of its existence, it is also an economic axiom that every consumer must, sooner or later, bear in some form the true cost of his existence in order to relate demand to supply. The customary mediator between man and the resources is the financial exchange system. Thus, the financial principle of quid pro quo cannot be separated from social systems of the distribution of resources and the adjustment of population and the level of consumption to the scarcity of resources. If urban centers are to survive they must live within their means by paying in fair value for the resources they consume. A fair market value for the water diverted should be paid by the consumers, based on metered distribution, and the proceeds should be distributed to the donors on an equitable basis, such as the length of stream frontage of communities downstream from the

diversion sites. It is certainly a violation of equity that communities in the M.D.C. area resell Quabbin water to support their tax bases at the expense of communities along the Connecticut. More fundamental, the principle must be recognized that internalizing the true costs of resources will reduce the positive feedback which promotes cancerous growth in urbanization.

IV SOME CONSTRUCTIVE SUGGESTIONS

We would like to make the following constructive suggestions and trust that they will be incorporated in the next draft of the environmental impact statement:

A. The report should state explicitly the projections of demand for water in the MDC system on which the report is based and should detail the assumptions which underlie those projections. In the preliminary draft report, this information is provided by means of a single graph, in the appendix labled "preliminary", with no elaboration nor explanation. This is a totally inadequate presentation of this important element.

1. What demographic trends are presumed? How might such trends be influenced by comprehensive, state-wide land use planning of the type that is being actively considered for the Commonwealth?

2. Will per capita consumption of water increase or decrease? By how much? On what sort of price assumptions are these projections based? One would like to know, for example, what costs are and are not reflected in the 14¢/1000 gallons figure cited as the cost of Northfield diversion water and what the cost of Plymouth County ground water was projected to be. (The latter figures are totally lacking in the present preliminary draft.)

B. There should be an evenhanded and complete statement of the costs of all alternative approaches. The present study is almost devoid of such numbers, and when they are presented, they are presented only selectively. What are the capital costs and the projected operating costs of each alternative method of supplying water to metropolitan Boston? Why, in purely economic terms, would one alternative be favored over another?

As a possible model for the economic analysis we feel should be presented in the environmental impact report, we cite the following summary, as prepared by the Natural Resources Defense Council, of the Draft Report of the National Water Commission (Nov. 1972), Chapter 8, "Interbasin Transfers":

> "The Commission proposes the following criteria to govern any interbasin transfer: a) it should be the lowest cost way of getting the water; b) the value of the new water uses should exceed the value of the former uses of that water plus all construction, and operation, and maintenance costs required to obtain that water via the interbasin transfer; c) an analysis of the alternative investment opportunities and the anticipated economic gain that might be realized from these should be made; d) the mere increase in regional economic development

attributable to the interbasin transfer should not alone justify the project; e) the beneficiaries of the transfer should pay the full costs of the project, including operation and maintenance, plus compensation to the area losing the water. In addition, an independent board of review, not the construction agency itself, should evaluate any proposed interbasin transfer. All proposals for interbasin transfers should be evaluated in accordance with environmental legislation in force at the time the proposal is made."

C. The preliminary draft report isolates each "alternative" and considers it in isolation against the diversion alternative, then discards it. The "alternative" of combining such measures as waste water recycling, groundwater resource development, local pollution abatement by land disposal of municipal sewage, increased user charges, desalination, and in the longer term, more sophisticated systems of domestic plumbing through revision of building codes should be assessed.

D. There is, to be specific, a notable lack of any explicit mention of land disposal of municipal sewage - a technique which the Army Corps of Engineers has championed vigorously in regions as close to eastern Massachusetts as the Merrimack River Basin. This technique offers not only the prospect of removing municipal wastes from surface waterways, but also it would recharge groundwater supplies in those areas where the technique is usable. It is disconcerting to find reference to the Corps' own studies and those being performed by the MDC on the same subject completely absent from this draft environmental impact statement.

E. The various attempts in the draft preliminary report to assess "socio-economic impacts" of the different alternatives are superficial, completely non-professional, biased, and totally unconvincing. If an analysis of these factors is to be attempted in the environmental impact report, a knowledgeable and neutral consultant should be retained to lay out the impacts on municipal revenues, growth in the residential and industrial sectors in receiver and donor areas, and the distributional effects. Is a diversion scheme, costing millions of dollars and having substantial impacts on the environment, being built so that the lawns of affluent Boston area residents do not turn brown in the summer?

F. At some point there should be an assessment of the construction impact. The preliminary draft statement admits the inadequacy of this analysis. (p. 83) The purported economic advantages to towns in the construction area would be boom-and-bust, not a permanent advantage. Such economics result in environmental disruption without long-term human benefit, and may result in hardship.

G. The report in several places refers to "other alternatives, outside the scope of the present project." (p. 61, 112) As required by the National Environmental Policy Act, the environmental impact statement

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must consider alternatives to the proposed action. As described in the introduction of the report, "the objective of the NEWS Study is the preparation of a coordinated general plan for essential water supply development in the Northeast which will recommend to the Congress an active program for Federal, State, local, and private organizations". (emphasis added) Thus, it is difficult to understand how there can be "other alternatives, outside the scope of the present project" unless the scope of the present project is, in error, defined narrowly to include only structural, interbasin transfer alternatives.

We stand ready to assist in the elaboration of the environmental impact studies along the lines that we have suggested they be elaborated.

Robie Hubley, Director
Arcadia Wildlife Sanctuary
Massachusetts Audubon Society

(CREAC)

CONNECTICUT RIVER ECOLOGY ACTION CORPORATION

Defenders of the Basin Ecology

COMMENT ON NORTHEASTERN UNITED STATES WATER SUPPLY STUDY (NEWS) SOUTHEASTERN NEW ENGLAND STUDY PRELIMINARY DRAFT ENVIRONMENTAL STATEMENT

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT, MILLER'S RIVER BASIN WATER SUPPLY PROJECT, DEPARTMENT OF THE ARMY, NEW ENGLAND CORPS OF ENGINEERS, WALTHAM, MASS. November 1972

The most critical issue of diversion is not treated in any substantial way by this report. That issue is implicit in the graph (page 63) which shows Quabbin empty by 2003+ regardless of the currently proposed diversions. In historical retrospect, it was promised when Quabbin was proposed, that the facility would supply Boston for 137 years (Ware River News, Aug. 8, 1895, p. 1). Instead, the abundant supply from Quabbin has been one of the factors resulting in the stimulation of growth, resulting in Boston's overtaking the resource in considerably less than the estimated period. It is absurd to accept that the whole Connecticut River will be diverted to meet demands of the M.D.C. area. Alternatives will have to be found in a short interval in terms of the times frames of technological and political developments. It seems from our viewpoint that those alternatives would probably be desalination, waste water recycling, local pollution treatment, groundwater resource development, fair user charges paid to the donor area, more sophisticated systems of domestic plumbing and groundwater recharge. None of these alternatives is adequately discussed in this report, with programs for implementation, as they should be were the problem to be realistically approached. Those interested in the continuance of the Connecticut River watershed ecosystem must be alarmed by the total failure to institute, simultaneously and by integrated programs, the means to a long-term solution.

The donor areas involved in the proposed diversions are not treated as systems. The report does not attempt to analyze food chains to determine the importance of what might appear minor organisms to the sustenance of other biota. For example, on page 37, it is stated that of 'many' fish species collected in the Northfield reach of the Connecticut River""...only a few...can be regarded as being important to anglers. These are: pike perch (walleye pike), black bass, yellow perch and catfish." Such statements invite the angler and the public to forget that no organism exists in a vaccuum, that each of the listed species is part of a complex food web. So, in reality, the interrelated assemblage of populations of such species of fish and the ecosystem which supports them must be considered. Systems analysis will probably not turn out, in the long run, to provide the whole answer to living within the ecosystem, but it is certainly the next step within our reach. It is being ignored in a conspicuc way by those seeking mechanical solutions to ecological problems.

The proposed diversions and consequent diminution of the flow of the Connecticut River are treated as inconsequential because they are said to be minor increments. But one increment added to another eventually adds up to 100%. It is important that the proposed projects be treated as additions to the existing Quabbin diversion, and that the impact of the whole out-of-basin diversion be analyzed. The proposed 1-2% transfer must be added to the 2-3% Quabbin transfer to assess the impact on the Connecticut River. It is in this context that the questions raised by Dr. Bernard B. Berger in his paper 'Social and Ecologic Implications for Out-of-basin Diversions' should be definitively answered before the proposals are undertaken.

It is becoming widely recognized that all economic and political sectors must begin to live within their means. While it is obvious that no region can produce all the necessities of its existence, it is also an economic axiom that every consumer must, sooner or later, bear in some form the true cost of his existence in order to relate demand to supply. The customary mediator between man and the resources is the financial exchange system. Thus, the financial principle of quid pro quo cannot be separated from social systems of the distribution of resources and the adjustment of population and the level of consumption to the scarcity of resources. If urban centers are to survive they must live within their means by paying in fair value for the resources they consume. A fair market value for the water diverted should be paid by the consumers based on metered distribution, and the proceeds should be turned over to communities along the river course downstream of the diversions to finance waste treatment and water management, or to a Connecticut River Authority with powers to manage and conserve the river. It seems certainly a violation of equity that communities in the M.D.C. area resell Quabbin water to support their tax base at the expense of communities along the Connecticut. More fundamentally, the principle must be recognized that internalizing the true costs of resources will reduce the positive feedback which promotes cancerous growth in urbanization.

It is our opinion that this report is written to justify a preconceived solution to the water supply problem rather than exploring and evaluating alternatives in a fair manner. It is possible that the requirement of the utilities to find multiple uses for the Northfield pumped storage facility has as much to do with the selection of diversion as a solution as the merits of the technique (see Charles H. W. Foster, 'The Northfield Mountain Pumped Storage Project Counterpoint to Con Ed', Harvard Forest Paper #19, 1970, no pagination). No discrimination of priorities is discussed in the presentation of alternatives - the report treats all as equals. The objections to development of the Plymouth County groundwater supply given in the statement (p. 131) are frivolous and inconsequential. If a fair price were paid to communities in the donor area the cost factor would be more favorable to the groundwater. Furthermore, the effects of diversion on recreation in the donor area cannot be accurately assessed without more knowledge of the effects on anadromous fish such as shad and potential salmon restoration. Unless further objections can be advanced, this groundwater supply should be considered preferable to interbasin transfer. We can find no evidence that groundwater recharge or wastewater utilization were seriously investigated. Such techniques would reduce demand and begin to close the cycle of water, assuring a continuous supply rather than putting the M.D.C. on an endless treadmill of seeking new sources. Simultaneous efforts should be undertaken to clean up the Sudbury and Cochituate Reservoirs and the Merrimack River. In addition, a pilot desalination plant, reclamation of waste water for appropriate uses, and an educational program to limit use should be undertaken. It is bad procedure to rely solely on one of the available sources of water supply, rather than developing a mix of several sources. We reject weather modification and diversion from the St. Lawrence River as means of supply. The first has implications more menacing than the supply problem being addressed, and the second is as bankrupt as a solution as Connecticut River diversion.

Frequently in the Statement grubbing, clearing and stripping and such disturbing activities are referred to as 'improvement', either esthetically or environmentally. Such judgements may be those of the authors but are not widespread or unchallenged attitudes.

The purported economic advantages to towns in the construction area would be boom-and-bust, not a permanent advantage. Such economics result in environmental disruption

without long-term human benefit, and may result in hardship. The argument that the diversion of water would be an ecoromic advantage to Boston and, since the donor area is in the same state, that that would be a benefit to the donor area (page 109) is a feat of mental gymnastics which is dubious at best. Indeed, the result would probably be overgrowth of the urban area, ignoring the resource base, at the cost of normal growth of the donor area, with net disadvantage to both.

We find no evidence that continuous and comprehensive monitoring of the Connecticut River has been carried out. Such monitoring, across the width of the River and continuously in time over a significant period, would seem especially appropriate where the intended use is human consumption, and where a reservoir of great capacity and value is at hazard. Cyanide events on the Connecticut River have been rumored. What would be the effect of such an event if it were diverted into Quabbin?

The wetland definition on page 51 is unacceptable, especially as it is used to avoid discussion of important aspects of the environmental impact of the proposal. A reasonable assessment of the impact of diversion on intermittent wetlands would be necessary, especially considering the significance of flooding in this system. Indeed, the impact of this diversion must be added to flood stage reduction by the existing system of flood-control structures, and the total impact on the estuary, floodplains, marshes, swamps, bogs, forests and wildlife, including anadromous fish, should be evaluated before further manipulation of the flooding event is permitted or undertaken.

Tom Sharpless, President

Robie Hubley, Board of Directors

Box 44
Hadley, Mass.

MILLERS RIVER WATERSHED COUNCIL, INC.

December 24, 1972

John Wm. Leslie, Chief
Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

Re: Preliminary Draft Environmental Statement
Northfield, Mountain and Millers River Basin Water Supply Projects

Dear Mr. Leslie:

The Millers River Watershed Council, Inc. have attempted to serve as the voice and the conscience of the donor area during the early discussions and public hearings relative to the above subject. We have endeavored to be completely honest in our statements both to the towns in the area and as we reported to the appropriate city, state and federal officials.

Thru our organization, the citizens review board and as private citizens we have presented questions relative to the concerns of the Millers River Watershed. After studying carefully the preliminary draft environmental statement, we can only deduce that the only concerns, felt by the Corps of Engineers study, are for the possible receiver area. The fact that the transfer of water, from the donor area to the receiver area, could cause the same and additional problems to the donor area, seems to have escaped the Corps attention. Any diversion of water, from a tributary of the Millers River, would be much like an operation where the healthy tissue is removed and the cancerous substance left in. The remainder of these comments will hopefully point out, to the Corps of Engineers, that the condition of the donor area is not "terminal", nor do we wish to become so afflicted.

Please keep in mind that we have not been, nor are we now, negative in our thinking. We believe that since we have offered the diversion of a legislated amount of water from the Millers River Only, after the quali of water becomes acceptable to the Quabbin Reservoir, points out the fact that we are responsive to the needs of others. If this plan, the Millers River Only, becomes the accepted one, we would insist the amount of the diversion be predetermined and agreed upon by the riparian towns and the Metropolitan District Commission. In addition, we would insist that the guaging station be established on the main stem of the Millers River. The figure of 17,000 cfs at the Montague station, as recommended by the Corps of Engineers, has no legal strength in this case and was established solely for the purpose of hydro-power on the Connecticut River.

"The Corps of Engineers and the state Department of Public Health say the Millers River Only plan is subject to so many variables that they are unwilling to speculate on the suitability of this supply under any given set of conditions. This is to say they will not allow this planned diversion until all questions have guaranteed answers.

"Yet the Corps of Engineers ask us to accept a plan which contains these phrases. "Although difficult to predict, it is reasonable to assume'....."The impact of these changes in water quality will probably be minor'....and, 'We view these changes to be insignificant."

One additional fact which seems to have escaped some of the reasoning used in arriving at a solution, is that the Northfield Mountain diversion should satisfy the needs of the Quabbin Reservoir until the early 1980's. The secondary treatment plants, along the Millers River, must be completed by 1976 thus leaving at least four (4) years to complete whatever necessary for the tertiary treatment necessary to accomplish the needed up-grading treatment of the Millers River.

"By the Corps' own words, the unknown factors involved in what it will take to clean the Millers River, will determine the timetable of the actual taking. We believe they have ample time to make this determination.

In closing may we say that we have read, copied and circulated the Environmental Guidelines For The Civil Works Program of the Corps of Engineers issued by the Dept. of the Army, Office of Chief of Engineers - Washington, D.C., dated Nov. 30, 1970 and entitled, THE NEED FOR REDIRECTION. We were impressed by it's words and the radical change of direction it spelled out for the Corps' decision making machinery. Yet, we find this preliminary draft environmental statement has lost sight of the "gut issue in that statement", that is, that a project shall not be initiated whose end results will cause irreparable environmental harm to the area, in this case designated as the donor.

"The Millers River Watershed Council, Inc. feels that the benefits of a clean and monitored Millers River, to our donor area, will be a fair and equitable tradeoff for a limited diversion of water from the Millers River Only."

We are prepared to take any and all possible legal steps, open to us, to prevent any diversion of water from any tributary to the Millers River.

Respectfully submitted,

Robert L. Gray

Robert L. Gray, Chairman

82 Charon Terrace
South Hadley, Mass. 01075
December 19, 1972

John Wm. Leslie, Chief
Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

I am enclosing comments and questions raised by the Environmental Quality Committee of the League of Women Voters of the Holyoke Area relative to the Preliminary Draft Environmental Statement "Northfield Mountain Water Supply Project--Miller's River Basin Water Supply Project". We believe that we have raised substantial questions that must, in justice, be answered. We hope that you will include our response as part of the Final Statement.

Yours sincerely,

Laura M. Stickel

Laura M. Stickel, E. C. Chairman
League of Women Voters of Holyoke Area

In reply to the Preliminary Draft Environmental Statement Northfield Mountain Water Supply Project--Miller's River Basin Water Supply Project", I wish to make the following comments:

(1) Few references to other persons' work (or works) are made, in the entire statement. In my estimation, no engineers could have prepared many of the biological comments without reference to biologists' work. Lack of citations prevents ease of a third person's checking any data given or statements made.

(2) The population growth figures are already out-dated and too great. (See Rosenthal, Jack. Census Estimate at Century's End Cut by 20 Million. The New York Times, Dec. 18, 1972:p.1.)

(3) Granted, the area is vulnerable to water shortages in drought periods, but I submit that it is those people who live in the so-called "water-rich" areas of Massachusetts who are restricted in their use of water at such times, while those who live in Metropolitan areas largely ignore any environmental crisis.

(4) Page 12, paragraph 4; concerns land requirements for the proposed diversion through Northfield Mountain Pumped Storage Facility. Question arises about the item "5 acres for rock excavated from the tunnel"--Will the plans leave the rock simply dumped somewhere, creating a 5-acre moonscape? Also, what effect will the removal of sub-surface rock have on the surface? This in itself needs detailed study.

(5) Page 13, paragraph 2; Just because the potential of diversion from the Miller's River to Quabbin was realized in the 1920's and 1930's, is no valid reason for carrying out this plan today and compounding the errors of "historical precedence."

(6) The effects of diversion on communities which abut the Connecticut River and are located south of the proposed diversion are not adequately dealt with. A number of these communities depend on flood plain wells for their water supplies now. Diversion will have an adverse effect on the annual recharge of these wells and a potentially disastrous effect on these communities.

(7) Page 37, paragraph 2; The value of fish other than those species important to anglers is not considered, but it is precisely these species which play an important part in the food web which sustains the sport species. The eggs and young of minnows and suckers may survive the Northfield facility pumps, but they will then be released to other water ways in poor condition. Thus they will be removed from their own "food web" where they are important as food for sport fish, and will be dumped elsewhere, where (a) they may not find their own food and (b) may become a pollutant themselves on decomposition.

(8) It is impossible to accept the statement (page 50, paragraph 3), "No changes are predicted for vegetative cover..." when later in the same paragraph it is admitted, "Higher areas which presently receive water infrequently, probably will receive shorter periods of inundation." The vegetative cover is highly dependent on not only average amounts of water, but on duration and season of water availability.

(9) Page 52, paragraph 1; Tarbell Brook Diversion--
The seasonal inundation of 40 acres of wetland to a depth of 5 feet will, I predict, create a mudflat bare of vegetation during the alternate season. This would promote erosion and siltation.

(10) The greatest part of the statement deals with the question of water quality and public health of the receipient areas, but these questions should also be considered for the donor areas--what will happen to the water quality of the donor areas, should diversion occur?

(11) Page 61. The no-diversion alternative is, on the contrary, the most realistic. The present system of operation of the MDC must be changed radically before the resources of western Massachusetts and, indeed, all the western New England area are funnelled helter-skelter eastward. The MDC at present must add any community to its system which chooses to join, provides the piping and guarantees purchase of an agreed volume annually. This creates a poor attitude toward water use. Because the communities must purchase a guaranteed volume, the local water resources are abandoned. There is a growing attitude of let "Them" take care of the problem. A few telephone calls recently confirmed what I had suspected--that we who live in the "Water Rich" part of this state pay generally higher water rates than do those in the "water poor" areas (eg., Holyoke's residential water rate is 70¢/1000 gals.). Differences are made up through taxation and bonding--"hidden"charges. This, too creates in the average citizen an illusion that water is "cheap" and can therefore be wasted without concern.

The Summary Sheet at the beginning of the Draft Statement lists a number of alternatives available for expanding the MDC water supply. Many have been eliminated from consideration because of "cost". The fact of the matter is that the only reason diverted water would be cheaper in terms of dollars is that it is simply taken without dollar payment. While the so-called "donor" area suffers inevitable environmental damage and potential future social and economic damage because its resources are diverted to enrich another area.

There must be an immediate return to use of local resources before any more water is diverted. In addition, desalination and waste water re-use programs must be examined for implementation. Future sewage building programs must separate sanitary sewers from storm sewers, so that storm water can be utilized. Building codes must be changed to encourage installation of the newer toilets that use far less water per flush as a means of water demand control.

We have long accepted the fact that water is a limiting factor for plants and animals. It is also a limiting factor for man. We are now beginning to see the wisdom of limiting the numbers of people using park sites--the same principle must be accepted in cities. Population zoning and regulations are needed to preserve the environment of the metropolitan areas as well as the environment of the proposed "donor areas".

Laura M. Stickel, Environmental Quality Chairman
League of Women Voters of the Holyoke Area
82 Charon Terrace

LEAGUE OF WOMEN VOTERS
OF MASSACHUSETTS

120 Boylston Street
Boston, Massachusetts 02116
357-8380

December 28, 1972

Mr. John Wm. Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts

Ref. NEDED-R

Dear Mr. Leslie,

The League of Women Voters of Massachusetts has reviewed the draft Environmental Impact Statement on the NEWS projects as they relate to the Northfield Mountain and Millers River diversions, and we have a few comments to make.

We recognize that any alteration of a natural system will have animpact, most frequently a negative one. We recognize that man's role in the natural system will always require some accommodation. We recognize that the alternative of no diversion in the subject situation is probably unreasonable under present constraints on population zoning as an alternative. What we question is the somewhat unbalanced values assigned to donor and receiver issues -- is the loss of a lawn any more traumatic to an MDC user than the loss of a trout stream to a Tarbell Brook resident? Fish and grass are desirable though not necessarily equal elements of man's environment.

NEPA requires exploration of all possible alternatives to a proposed project, including the alternative of no project. We feel that some of the alternatives are rejected without benefit of the depth of analysis and research given to the proposed diversions.

1. Re water demand control, are nationwide figures on categories of water use comparable with categorical uses in the MDC communities? Is Akron, Ohio's domestic use percentage breakdown a valid indicator of MDC use patterns? We realize that, for the purposes of the NEWS study, figures were not available to determine how much MDC water is used by whom and in what manner, but we believe that these statistics must be developed before the alternative of demand control is negated. (We regret that use categories were not measured as diligently as shad eggs.)

2. Re pricing restraints, is the Seidel & Baumann assessment of the minor effect of rate adjustment on demand relevant to MDC? MDC users have been castigated for not paying their water's worth, when in fact they do and then some, for the difference between cost and price is paid through MDC assessments on local taxes with the addition of an annual share of the deficit financing that characterizes MDC Water District management. Because this overpayment is not immediately obvious to the customer, water is not regarded as the limited resource in need of conservation that it really is.

A telephone survey that determines that only 8% of MDC water is used industrially does not tell us how much of that use does not require this high-quality water - we note that this 8% of projected demand just about equals the 48 mgd that would be diverted via the Tully Complex Alternative #3.

The MDC is engaged in a recently-authorized study of its water supply system. We would hope this study (which contains some of these elements of concern to us) could be completed and its results analyzed before commitment is made to further diversions to Quabbin.

3. On reuse of water, another MDC study is focusing on the future of the sewerage system. Hopefully it will find a way for member communities to assist in the natural cycle of water use, discharge, recharge, and reuse, thus enabling members to draw more responsibly on their local resources instead of pouring millions of gallons into Boston Harbor and reaching out for fresh supplies from someone else's backyard.

It may well be that in the long run the proposed diversions are the only reasonable means of serving the MDC system which supplies 40% of the state's population and is under pressure to serve more. We have stated before and we repeat here our belief that a justified need must be met. The waters of the Commonwealth belong to all its people, and Massachusetts as a whole benefits from the economic, environmental, and social vitality of any one of its regions. Such developments as transportation systems, hospitals, and institutions of learning are carried out statewide with statewide support; resource needs must be met in like manner. Our concern is that not enough specifics have been dug out about use patterns in the MDC area to make a balanced judgement possible.

Probably the most dramatic statement of impact is that even with the proposed Connecticut and Millers diversions, Quabbin in 1998 will have reverted to its present volume and begun to

deteriorate. That's a lot of activity only to find oneself in 25 years back where one started. To continue diversions without imposing responsibility on users merely continues the illusion that there's plenty more where that came from and it's cheap. In view of the magnitude of the proposed projects and their relatively short-term effectiveness, the League hopes that more work can be done in the areas described above before further diversion commitments are made.

Very truly yours,

Margaret Lynch

Mrs. Charles E. Lynch
President

Rita Barron

Mrs. Rita Barron
Water Resources Chairman

LAKE COCHITUATE WATERSHED ASSOCIATION, INC.
1143 WORCESTER STREET, NATICK, MASSACHUSETTS 01760

Kindly reply to: 61 Lake Shore Road, Natick, Mass. 01760

December 20, 1972

NEWS Study
U.S. Army Engineeer Division, New England
424 Trapelo Road
Waltham, Massachusetts 02154

Gentlemen:

The Lake Cochituate Watershed Association has evaluated your November 1972 preliminary draft environmental statement on the Southeastern New England (NEWS) Study, and recommends several additions and changes.

On pages 137 through 150, your report addresses itself to the possibilities of Water Demand Control. We appreciate the addition of this consideration to your study, as it represents the other half of the supply-demand equation which hopefully will stay better balanced in future years. And, as vividly depicted by your page 63 graph: "Projected Quabbin Reservoir Volumes with and without Diversions", planning without this half of the equation merely (but at great expense) forestalls the inevitable confrontation. These comments of ours are now supported by the November 1972 Reports of the Mass. Citizens Task Forces on Environmental Reorganization, specifically Concern 6, "Master Planning for Water Supply", discussed by the Water Resources Task Force on pages 328 and 330 of that report. We ask that these two pages be added to your report or its appendix.

In view of the importance of demand moderation action, we believe that your report's treatment of this subject area is superficial and weighted toward inaction. For example, your report indicates that 19% of water demand is used to carry away domestic wastes nationally, and suggests that an even greater percentage applies in the MDC user area due to low industrial demand. It would then seem significant to encourage the Sanivac waste-flushing system and others which might reduce flushing water demand by 90%, to discourage indiscriminate use of drinking-grade water, and to propose steps to accomplish these ends (revision of building codes, incentive tax techniques, etc.). Yet, under methods for controlling demand, you do not even list incentives for more efficient use techniques, let alone discuss them.

Similarly, we believe that a fifth category for controlling demand might be listed as public awareness programs - correction will only follow motivation, which follows awareness. Discussions of the implications of this comment are completely missing, although on page 155 the report quickly mentions (and then begs off from acting on) the ultimate need for population growth or water quantity restrictions if someone doesn't do something to

moderate demand. Who, if not you and your study? When, if not now? What percent of total projected expenditure do you believe should go into positive demand-moderating programs?? Intelligent political decision-making must rely upon the degree to which you choose to treat these issues!

In this section of your report, greatest attention is devoted to increasing the price of metered supply. Your conclusion is that this alternative may have merit, but that much work remains to be done. By whom? Again, where are your suggestions regarding this? And why is your evaluation of the pricing system limited to linear increases, at still-too-low levels? If you wish to produce different statistics than those quoted in your referenced studies, why not suggest a waste-inhibiting price scale (base quantity per capita free, then quickly rising rates for luxury usage, for example)? But even in the studies quoted, a more positive attitude indicates a different approach: in the case of the privately-owned water company price increase (page 148), we do not agree that a rate increase should necessarily "be expected to result in a demand decrease" - not in view of the rising demand curves you have presented so well elsewhere. A lowered rate of demand increase would be more reasonable to expect. Did this company's use increase represent a decrease in this second derivative relationship?

Based upon the above comments, the LCWA urges that you include in your final report specific commitment to the finance and development of realistic demand moderation programs in parallel with supply projects, and that you temper your discussion and examples more accurately to this end.

Concerning an historical and less controversial matter, the LCWA recommends that you amend the discussion of Sudbury River water potential on page 136 of your report by the substitution of the following for the first paragraph:

"In 1846, the Cochituate Reservoir (previously Long Pond and presently Lake Cochituate) was acquired and developed to meet Boston's water needs through diversions from a subdivision of the Sudbury River watershed. In 1872, the Sudbury River Act was passed which authorized the diversion of a portion of the Sudbury River mainstream to the Boston Water System. Subsequent to this Act, a series of reservoirs was constructed by the Boston Water System and later by the Metropolitan Water District to further develop the watershed. Construction of the last reservoir in the basin was completed in 1898 and a total of 75.2 square miles of drainage area was controlled."

The LCWA appreciates the opportunity to interrelate with this important project.

Sincerely,

A. Richard Miller

A. Richard Miller
Executive Director

The solutions ,or alternatives that the Corps have proposed are not long-range solutions to the water -supply and demand problem. They are a mere purchase of time, nd folly which will deplete the watersheds of water necessary to their riverine environment.

? This preliminary draft environmental statement is not an honest assessment of the impact the proposed diversion,out of its natural watershed will have on the watershed. It is a collage of carefully chosen words all playing down or minimizing the impact on the environment, of inter-basin diversion. Because the potential of the Millers River Basin as a water supply source was recognized in the 1920s does not necessarily mean that the solution is a competent one or the sole answer to the water supply problem.

The statement that the socio-economic impact on the donor area is to be positive is highly questionable, and a direct contradiction of the fact that there can be no guarantee made on the quality of the water at the time of diversion either in the basin itself or in Quabbin Reservoir. It is also a well known fact that labor forces for the project would consist of out-of- town help.

If large socio-economic impacts are to be felt by towns supplied by the Quabbin-Sudbury system in a "no go " situation the fault lies solely in the hands of the Metropolitan District Commission for their failure to actively and consistently urge conservation in domestic and industrial usage.

I refer now to page 150 and the summation . People are aware. People are concerned and the average consumer is willing to curtail his consumption of water . We have been and continue to a sk for a voluntary curtailment. The M.D.C. has no basis to condemn an approach they have not even tried. 1960 is not 1972 or 1975.

Page 26 again refers, in depth, to the Priest Brook alternative. This has been repeatedly denied as an alternative by the Corps , yet it is still, in fact, a viable consideration. This alternative is definitely damaging to the great natural beauty of the area and by it inclusion throws considerable doubt on the credibility of the entire preliminary draft environmental statement.

Silting is obvious on Royalston Road north from a recent construction project on the Priest Brook. Yet the Corps concludes that silting is minimal. This area has a fine sand content which is very high and the lack of a current survey on silting again casts doubts on the credibility of this statement.

The East Branch Tully River again is a classic example of the lack of consideration given to the natural environment by the Corps of Engineers. The eight miles of wetland definitely bound to be affected by a loss of water necessary to the riverine cycle. (p.61) Wetlands are wet all year round due to the water derived from that watershed. So where is the data that you base no impact from diversion on here?

Short term solution is amplified for the period 1989-2000 on pgs. 59 & 60. The statement " we envision probable changes"... shows the type of guesswork encompassed in this statement. Page 63 has a chart which diagrams the 8 yr. period that Millers can competently handle the demand. ? 33 million for an eight year solution is foolish. Would it not be wiser to put that amount into research of desalination and into recycling water to industries for cooling machineryand to homes for sanitary flushing?

Again we call attention to the inclusion of Priest and Tarbell Brook.(p.66)

How is it that no odor was detected at Millers River? (pg. 70) Also ,what data backs up the statement on low significance of impact on page 79? [illegible] general assumption [illegible] these assump-

tions are supposted by facts not wishful thinking.

"Long term impacts should be minimal" is a rash assumption and a direct contradiction the statement that long term 20 year projection is definitely toward a lower water quality from the impoundment areas.

On page 83- The construction phase of diversion is a definite ingredient on environmental impact. The validity of an impact statement not including it is questionable.

I call attention to paragraph # 2 on page. 99 that states that the spring freshet is an important factor in shaping the river and that major alterations of the flow , such as diversions, beyond the presently postulated limits will be reflected in changes in the morphology of the river. This has been a principle objection from the start. You, the Corps, can give no guarantee diversion below the presently postulated limits will not also definitely affect the watershed.

Page 103 gives a chloride table dated 1935-1937, which is insidious by its inclusion. More current data must be furnished to give a more credible statement on impact.

Page 106: I could write a better soap opera. The estimate loss of 600 classrooms is sheer hysteria, and stupidity. If each of the categories listed were to implement conservation practices the savings alone in a no go situation would be beneficial. If industrial, and commercial categories employed recycling to cool machinery the drain on Quabbin would have to be cut in some manner.

Also, when you speak of concrete losses what of the taxpayer who has to watch $ 38 million be spent on the purchase of time by seemingly intelligent engineers instead of those same engineers investigating more progressive solutions. If citizens watch their lawns dry up suggesting that their hidden hostilities will suddenly become rampant is absolutely ridiculous. A little Yankee ingenuity in your part would go a lot further.

Those impacts felt by supplier area peoples are not tangible. They are the definite destruction of beautiful wooded and scenic areas.

Fellows. This most "adamant" opponent of inter-basin diversion is amazed at your simple minds.(p.109) Moral outrage is not our gripe. The need to more progressively meet water demands is staring you in the face and you can't open your minds long enough to realize it. The definite environmental damage that is so callously played down in this book should not have to happen.

We are not outraged at " being forced to give up our water". Rather we condemn the concept of inter-basin diversion which removes water from its natural watershed and does not return it. Where is the insurance of a healthier Millers and a better aesthetic environment at Priest Brook?

If diversion would insure a cleaner river than otherwise possible under the present implementaion schedule it is only because politicians are playing games. Why have business known to be polluters been given reprieves time and again for installing the necessary equipment?

Page 110. There is no basis for the astoundingly ridiculous statement that there will be no appreciable impact on the Millers River watershed.

Page 113. Note in final statement please that the current high record rainfall has continued into 1973. This has to be taken into consideration.

Page 114. Again I suggest you are stretching your own frustrations into the statement in Paragraph # 3. Instead of suggesting hidden hostilities why not include the National Wildlife Federation survey(1972) that shows people are willing to conserve? And also curtail their own luxury living to help preserve the environment.

The analysis of desalination is fair but you continually deny the expense of diverting [illegible] will leave

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ou with a water supply problem in the years 1989-2000.

? d the money refining the more progressive alternatives.

xtra- regional sources is foolish as it is environmentally detrimental to the basin donor .

aste water re-use-- No one has sugrested direct consumption of drinking water that hasb een recycled. Instead we have urged the Corps of Engineers, the M.D.C. and the overnment to demand that recycled water be used in industrial cooling , irrigation, and s a definite source of water for sanitary flushes. Dragging thalidomide into the icture again suggests hysteria on youb part. Do you all drink out of the toilet bowl?

I would like to see the preliminary draft environmental statement change into an onest forthright believable assessment of the environmental impact of the proposed nter-basin diversion. As it now stands ,it is a sad portrayal of the quality of ntelligence put forth by the Corps.

Celeste M. McQuillan, secretary of S.O.S .

P.S. I would like to be sent a copy of the draft environmental statement and the final environmental statement.

South Main Street
New Salem, Mass. 01355

December 28, 1972

Department of the Army
N.E. Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

RE: NEDED-R

Gentlemen:

It is clear from the preliminary draft of the environmental statement on the Northfield Mountain and Millers River Basin diversions to the Quabbin that the Connecticut River Diversion through Northfield should proceed. The dangers and possible damages are low relative to Quabbin damage if the water level in the reservoir continues to decrease.

But the Millers and Tully proposals seem to me much more questionable in total environmental impact. With my present confused understanding of the donor area result I cannot enthusiastically vote for the project even though my concern for the Quabbin prods me to do so.

I am disturbed by the easy acceptance of public disapproval of water use restrictions as ". . . found in newspaper clippings during the recent sixties' drought," as meaning that restriction does not offer a viable alternative. It seems to me essential that this study point out emphatically that control of use of this high quality water should be started soon. Education of the MDC system users should proceed rapidly so we will not be faced with the same problem a generation from now when the donor region supplies are gone. MDC should stop being just a salesman for water and start selling conservation of supply.

Very truly yours,

C. Russell Shaw

C. Russell Shaw

In reply to the "Preliminary Draft Environmental Statement" prepared by U.S. Army Engineer Division, New England, Waltham, Mass. of November 1972.

It staggers the imagination of the average private citizen with limited means and without proper research staff or training, such as myself with the prospect of taking up the task of challenging a well staffed and funded project such as this report of 158 pages and some odd maps and plans represent. Take up the challenge I must, for I am the principle landowner in the Priest Brook project area. Although you failed to mention on page 35 that there is also a Tree Farm project containing more acreage than the combined holdings of the trailer park and rod and gun clubs. And I might add, a place where one can already hunt, fish, hike, nature study and pick berries without a chain link fence or gate or special pass to acquire at the sufferance of some indifferent state or federal employee. So, you can hardly claim that your stewardship can add this as you do on page 52.

In the first place, I fail to see how the combined waters of the Tarbell and Priest Brooks could possibly solve the water problems of the M.D.C. Two very scenic and still wild brooks are to be sacrificed for what certainly must be the ultimate in "Rube Goldberg" engineering. Is the effort and cost and certain distruction of important reaches of two still wild brooks with the little water you may acquire in "skimming the flood"?? Can you really expect anyone to believe the last paragraph on page 157 ((Structure can be removed and the land restored to its former condition?)) The deposits of sphagnum moss and fine grained sands and silt that have accumlated in the Priest Brook project area which you propose to "Strip clean" have taken time that can only be measured against the geological calendar of events to put in place. And you think that if the project doesn't work that you can restore the land so stripped to its former condition? You may sell that idea to some person that doesn't think or reason, but try doing it to one that does.

On the question of land ownership, it will be found on page 55, third paragraph, "Nearly all riparian rights along the reaches of Tarbell and Priest Brooks affected by the proposed diversion are controlled by the Corps of Engineers Birch Hill Dam." One wonders what the Corps of Engineers interpolation of the words, "Nearly all" mean? If it was calculated to impress some future reviewer of your study that little private property will be taken, then I must take exception for it is grossly in error. The riparian rights controlled by the Birch Hill flood control project located

down stream from the Priest and Tarbell Brooks project sites depends on the elevation of the spillway which is 852 ft. above MSL. In the case of the Tarbell Brook project which it so happens requires the least land you are entirely correct in that it is entirely controlled by the Birch Hill Project. On the Priest Brook project where the greatest amount of land taking is to occur in the entire Tully Complex, the location of your dam at elevation 855 feet above MSL is slightly out of the Birch Hill Flood control area. It would be charitable to say you had reparian rights to five acres. If the elevation of the spillway at Priest Brook Dam is to be the controlling factor in land taking (875 feet above MSL) or the elevation of the top of (890 feet above MSL) than it is in my opinion necessary to condemn at least 1000 acres. The final figure naturally will be considerably more since many tracts of land will be left without access and will be of little use to their present owners. I was told at one of the hearings in Waltham by one of your project study group that "We take back 300 feet from the highest of the high waters." So that if you add this protective belt of 300 feet around a 400 acre "pool" you add up the acreage very substantually. So it will be seen that the words "Nearly all" are construed by this writer to be a means by you to deceive the unwary reader.

The statement on page 157 "No known endangered species of birds or animals utilize the proposed project lands. The amount of nesting habitat for migratory species will remain essentially the same in the region as it is at present." In the Priest Brook project site, the area I know best, I find this just a little hard to believe when we examine the facts. Reasoning tells me that if you remove the vegetative cover from the surface area of the wet lands to the extent of 400 acres, that it will considerably diminish the available nesting sites for that species that now seasonally inhabit the area, but what is even worse is that the natural breeding sites of the insects in the low wet land are the natural food for a whole host of birds that inhabit the nearby area. Not having specific knowledge of the subject I asked an old acquaintance that does have some little knowledge of the subject. This acquaintance and his wife have banded over 43 thousand birds since 1937 and has served on a joint study project with Canada on migratory birds that has been published a number of times. He has a graduate degree and has spent his life in the academic world. Although he has not lived locally for a number of years, no man has a greater first hand knowledge of the Tarbell Brook area than he. Now over eighty years of age,

he was born on the old family homestead on the banks of the same brook. His family settled there a few years after the revolution. When asked if any particular species of bird would be endangered in the area, his prompt reply was, "I don't know of any species that isn't in danger including man himself." Certainally I know the same as you that the "passenger pigeon" is forever gone and that nothing quite so exotic as the "whooping crane" nests in the area, but I do know, the same as you should, that if you keep removing natural nesting and feeding areas that the laws of diminishing returns must eventually be invoked against us all. Even in my short life span, I've seen the once numerous "blue bird" become a very rare sight. I wonder what background your authority had to make his statement from? And how long was his stay in the area in question? Or is it the result of another computer "impute" to use a term that your staff always seemed to refer to whenever confronted with a question at your public hearings.

To fully understand how you arrived at the figures of possible economic losses to the receiver communities and the estimates of losses of "say 600 classrooms," or that the water sprinkling industry is something even to be considered (page 100). One has only to read your contract awarded to the ADT Associates, Inc., for the "Socio-Economic Impact Studies," and what information they are expected to bring back to earn their carrot. Under section 3, Contract Services, subpact "E", "for alternative go" "no go" scenarios. The scenarios to be considered are: etc. & etc."

In other words bring us back a comic opera. For example, "frustrated as they see their lawns dry up during watering bans," (page 107 & 115.) Or the Socio-economic Impact Measurement table - with its 20 "Impact Categories" and suggested measures. Anyone of these 20 "Impact Categories" listed can only be answered by "extrapolation." Never forget for one moment that in the rules of evidence, that a guess whether it is learned or otherwise is as good as useless and at best can only be used as a clue. The burden of proof still remains upon you and no amount of manouvering will relieve you of that duty. I for one would like to believe that I came from a nation of people that wouldn't become frustrated just because they couldn't water their lawns, and I would hope that you would entertain the same belief also. For if it is not so and our people are so morally bankrupt as that, then in my opinion all is lost.

On page 155 under the title of "Population Zoning and Regulations" we find the rather interesting quote, "A question of constitutionality to the

principle of popluation zoning." Most of the cities and towns of the Commonwealth already have zoning laws. Granted that for the most part they are merely building codes, but in effect are they not really population zoning in mild form? If one cannot build a house or factory in a certain area, couldn't it be considered as a means of limiting growth? I don't have the means at this isolated homestead to ascertain if the Constitutionality of the existing zoning laws have been tested in court. I can only assume that if they had a ruling against them, that they would no longer be in effect and that since they still remain on the books then it is a logical assumption that they are not depriving anyone of their Constitutional Rights. As for Constitutional Rights in real property, the tenure system is not spelled out in a single basic document. It depends heavily upon the common law and court decisions, rather than concise statutory enactments. It evolved slowly before and during the colonial period. Most of the breaks with the mother country's tenure system were formalized in statutory enactments or were developed in practice by the time of the Constitution. For this reason it would appear that Constitutional questions do not arise out of zoning legislation which has to do with land use. I would assume that if a question of Constitutional Right does exist to the "principle of population zoning," then certainally I should have the same protection against the politically powerful in the urban centers from exercising the States right of "eminent domain" upon me to deprive me of my right in property. Whatever the answer to this question is to be, you can be sure that before your proposed project on the Priest Brook is started, the courts will have to decide. For I can assure you that there is no other way.

I've been told that I don't stand a chance in answering the challenge. Especially in view of the original Quabbin Reservoir Project when 4 towns were taken with 83,500 acres and more than 2,500 people living in 650 homes were required to leave. Not even the ancient burial yards containing 7,561 bodies were spared. However, since April 26, 1927 when a special Act of the Mass. Legislature, created the Metropolitan Water Supply Commission a new awareness has come to pass in the last few years that we must put a limit upon the indiscriminate use of our land and natural resources or we shall all be destroyed. You may find it hard going to get a judgement against me.

The question of alternatives to the present proposal plans for implementing the diminishing water supplies in Quabbin Reservoir has at all the hearings and in the present study in question been thrust before us as if

it were our duty to solve the problems of your alleged dilemma. I cannot see where any such burden can rightfully be placed upon us in the donor area. What you have been saying is, "Jean, I'm going to burn your house down, What alternative will you give us?"

Through the so-called miracle of modern engineering this Commonwealth's greatest metropolitan center has been completely encircled with a vast asphalt desert. Any water that might percolate down to the water table for many miles around has been very effectively channeled off through paved ditches and storm drains so that it will quickly run off into the sea. Hundreds of thousands of once valuable acres have been paved over for parking lots, freeways, access roads, etc. Did it ever occur to anyone that your problems are self inflicted? Did it ever occur to anyone that no generation since the founding of our country has been without war, and through the miracle of modern engineering that your greatest metropolitan centers have been made so vulnerable that less than a weeks' siege by modern warfare would be their ruin? I don't even dare to think of what could happen to the water supply, least I be accused of plotting against it.

But there it is all before me, and the danger seems so self evident to me, a common lay-man, that your safty perhaps rests in the fact that no professional military planner would believe it to be true. Are you to continue on the same dangerous course? Is it not time to have the moral courage to say "No" to somebody?

Jean A. Simoneau

55 Union St.
Gardner, Mass.
25 December 1972

Mr. John WM. Ieslie, Chief, Engineering Division
Department Of The Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

I am pleased to forward to you the following views regarding the Preliminary Draft Environmental Statement on Northfield Mountain Water Supply Project-Miller's River Basin Water Supply Project, dated November 1972.

At the outset let me state that I firmly believe a depleted Quabbin Reservoir would constitute a catastrophe of the highest magnitude. Further, it is my opinion that any projects or manipulations to alleviate such a situation should be held to main stem where absolutely possible or close to main stem where absolutely necessary. In my estimation the impacts related to Alternate # 3 of the Miller's River Basin Project make that offering unworthy of consideration.

My criticism is hopefully constructive, and in no way is meant to degrade a relatively well written draft.

On page 19, under Alternative No. 2 - Tully-Millers Diversion, first paragraph, penultimate sentence states, "As in alternate No. 1, waste treatment plants on six point sources of pollution would also be required". Yet on Page 16, under Alternate No. 1, middle of page, a sentence reads, "Based on our evaluation, it appeared that the river, even after proposed secondary treatment "clean up," might require additional or advanced waste treatment at the point sources of pollution. It is understood that waste treatment plants on six point sources of pollution on the Millers have already been guaranteed by Mass. Div. of Water Pollution Control by 1976, whether any diversion is Go or No Go. Perhaps the previous mentioned sentence on Page 19 should read: "As in Alternate No. 1, advanced waste treatment plants ---- would also be required".

On page 21, regarding Miller's River, last sentence reads. "But, neither would the flow be augmented when it was naturally below the control flow". Since the same procedure would apply for diversion of East Branch Tully River, and release of flood control water enters in, the exact position of flow monitoring stations must be spelled out.

During deliberations at CRC on the Conn. River Plan, a 17,000 cfs figure was used in conjunction with hydro-electric studies and flow releases from power dams. Is this figure appropriate for diversions? I mention this because releases from power dams might affect the flow regimen of the Conn. River main stem, and this in turn might have an unnatural effect on the diversion from tributaries.

On page 25, under Alternate No. 2, second paragraph states, "But also provides flood control protection on the East Branch Tully River." Page 24 says, "Flood control protection attributable to this alternative are minimal." Also on page 25, second paragraph, is found: "Some 30 miles of streams would become excellent quality ----." This comes under general discussion of Tully. Streams in the Tully area are already excellent as witnessed by Tully Reservoir Diversion under Environmental Setting Without The Project, last paragraph P. 35.

On page 49, Miller's River Alternatives - Environmental Impact Of The Proposed Action, a key sentence is this: "Considering future water inputs to Quabbin Reservoir it must be borne in mind that Alternate No. 1 or No. 2 would not be implemented until water quality of the Millers River meets all public health as well as environmental standards present at Quabbin." If this be true, and the statement is not taken out of context - also considering previous statements likewise, it would seem that the greatest loss to Quabbin from Alternative No. 1 might simply be 8 MGD. The difference between Millers 68MGD and Millers-Tully 76MGD.

Phase II of the proposed diversions represents a period 1976-1980. This constitutes Conn. R. diversion only. A peak at Quabbin is reached in '84. Bear in mind a "cleaned up" Millers River (secondary treatment) has been guaranteed by Mass. Div. of Water Pollution Control for '76. Considering next that a ten foot tunnel from main stem Millers to Quabbin with its inlet and outlet structures are necessary under either Alternative No. 1 or No. 2, and might be constructed in initial stages of either alternative; it would seem (to a layman) that a satisfactory time frame for an evaluation of the so called "cleaned-up" Millers might be available, leaving the Tully-Millers Alternative appreciably engineered, constructed, and standing by. USING ALTERNATIVE NO. 1 AS A GO.
Certainly the concept of stage development as a tool by water resource specialists is clearly understood; however

every possible understandable effort must be made to preserve and safeguard free flowing tributary streams that future generations might have an option. This especially considering possible future technological break throughs. The fish and wildlife as well as aesthetic values and their associated socio-economic impact alone is appreciable.

I thoroughly understand the necessity for a relatively full Quabbin with quality water, and have written several sporting articles relative to that resource. The opportunity for sharing these views is appreciated.

Sincerely,

Warren M. Sinclair

The Commonwealth of Massachusetts
Holyoke Community College
291 Pine Street
Holyoke 01040

TELEPHONE: 536-1624

December 21, 1972

Mr. John Wm. Leslie, Chief
Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

This letter is in reply to your "Preliminary Draft Environmental Statement for the Northfield Mountain and Miller's River Basin Diversion Proposal for the Northeast Water Supply Study". I wish to express my thanks to you for giving me this opportunity to comment on the Environmental Impact Statement (E.I.S.).

My discussion of the E.I.S. is separated into two sections: A) Presumed Typographical Errors, and B) Differences between my philosophy and that of the Corps of Engineers and the Metropolitan District Commission with respect to providing water for increasing human demands.

A) Presumed Typographical Errors:

1) Beginning on Page 21 and thereafter of the E.I.S., several abbreviations are used for which no definitions are given. These abbreviations include CSM, MBAS, $\Delta QR = \Delta QL$, and CCE. In my opinion, the final statement should define these abbreviations.

2) Beginning on page 41, and thereafter, citations are made from several publications, but no bibliographical sources are included at the end of the E.I.S.. This should be rectified.

3) On page 73 (line 12) you state, "A comparison of study data with other available data suggests COD values for the Connecticut River are about two times as high as for the Quabbin 'inside' station..." In Volume II of "Water Quality Studies, Connecticut and Miller's River Systems and Quabbin and Wachusett Resevoirs, Massachusetts" (New England Research, Inc., Nov. 1971), the statement is made on page 60, line 20, that "The COD values of Quabbin 'inside station' are not much different from those of the Connecticut River". This discrepancy should be dealt with in the final E.I.S..

4) On page 88 of the E.I.S. (line 20) the statement is made that "Since the temperature and salinity rises are so small ($\underline{72}$°F. and a few Mg/L) at any given point...". On page 13 (line 10) of "Possible Effects of Various Diversions from the Connecticut River" (Essex Marine Laboratory Report #2, May 1972), the statement is made, "Since the temperature and salinity rises are so small ($\underline{\leq}$ 2°F. and a few mg/l) at any given point...". The final E.I.S. should deal with this discrepa

5) Since you quote so liberally from New England Research, Inc. and from Essex Marine Laboratory reports, I think it only fair to the scientific community which will be examining the E.I.S. critically that full reference to those reports, as well as to any other reports contracted by the Corps, be made in the final E.I.S. and that these reports be readily available to interested parties.

6) In your conclusions as to why a groundwater alternative is not in the best interests of the state as a whole (page 131) you fail to mention exactly how much more costly ground water would be. The final E.I.S. should do so, in my opinion, and should also relate this cost (as well as other alternative costs) to the fact that the MDC will not be paying the western end of the state for water skimmed from the Connecticut and Miller's Rivers. The lack of payment for water to be "skimmed" from the western watershed obviously makes a much more attractive alternative.

B) Philosophical Differences

Generally speaking, I was distressed to see that in the 158 page E.I.S. that although you did devote 22 pages to an examination of the the estuary and its relationship to the proposed diversions, only five pages were devoted to the immediate donor areas (i.e., the Connecticut River at Northfield and various diversion schemes from the Miller's River System). It will not be my intent here to give an overall philosophical discussion of why this diversion plan should be abandoned (see Connecticut River Ecology Action Corporation and Connecticut River Watershed Council replies for this) but rather to concentrate my remarks on specific points.

1) Flood skimming at 17,000 vs. 12,000 cubic feet per second (cfs): On page 10 you state that 17,000cfs is the limit at the Montague gauging station below which no water will be taken from the Connecticut River System (this critical flow specified in current Massachusetts legislation). Yet you do not cite any scientific rationale of an environmental nature for the 17,000cfs figure and frequently elsewhere (pages 84,89,93,99,104, and 105) cite evidence as to the lack of expected damage if 12,000cfs were set as the low figure at the Montague gauging station. Not only is one left with the impression that the eastern end of the state will come back for more water once Quabbin again begins to run dry (your figure 1, page 63 strongly suggests this), but one becomes extremely concerned in light of the Essex Marine Laboratory report statement on page 14, and 15:

> "1. Until considerably more work is done to fully delineate the physical and biological parameters of the river, the controlling flow for diversion should be considered at no less then 17,000cfs at Montague City.
>
> 2. Research in connection with the preparation of this report revealed the extreme paucity of relevant data, both physical and biological. Rational decisions involving alterations of the natural regimen of the river are difficult in the absence of such data. A program should be undertaken without delay to provide the information which will be required as future demands arise for new uses of the river.
>
> 3. Specifically, in the biological field the following

are among the most pressing needs.

a. The biology of the lower river at and below the fresh-water-saltwater interface is little known. A complete biological inventory is essential if the possibility exists of future alterations which would affect this area.

b. While some work is presently underway, there is much to be learned about the homing mechanism of the shad, and the effects of temperature or of flow volume and velocity on its spawning migration. The same parameters may well effect the population dynamics of other fish and lower species in the food chain.

c. If the current attempt to restore the Atlantic Salmon to the Connecticut River is successful, the requirements of this important species must be intensively studied to safeguard its continuing existence.

4. A three part program for delineating the physical and chemical characteristics of the river is required to provide information needed not only for future decisions, but to assess the effects of alterations presently in the planning stage.

a. A continuous in situ monitoring system should be established to measure such common parameters as temperature, dissolved oxygen, conductivity, and flow velocity. The technology for such a system is readily available, and considerably less expensive than it was even a few years ago.

b. An hydraulic model of the river should be constructed, using the data from the monitoring system for calibration.

c. Data from the monitoring system and the hydraulic model would make possible the design and calibration of a mathematical model. Such a model would make it possible to test the effects of proposed changes in river utilization at a very reasonable cost. Attempts to mathematically model the river in the absence of real physical and chemical data have not been satisfactory."

2) Lack of concrete information that diversion will not have a detrimental effect on the donor and recipient areas. In several places (see page 37, line 1; p.42, l. 3; p.72, l.7; p.75, l. 22; and page 82, line 22 for some specific details) the E.I.S. is is unable to predict with any certainty the effects that the proposed diversions will have on the physical, chemical and biological balances and quality of drinking water of either the donor or recipient watersheds.

3. Lack of sound data on the affect of diversion on donor ground water supplies. On page 110, line 22, the E.I.S. states that "...no appreciable impact on the hydrology of the Miller's River watershed is expected." This statement is misleading in light of Berger's paper ("Environmental Aspects of River Diversion" in Forste, R. H. 1971. "Proceedings of the New England Conference on River Diversions" Water Resources Research Center, Univ. of New Hampshire, Durham. 162pp.) which states (page 29-30) concerning diversions from the Connecticut River in general:

"A diversion of 72 mgd, the proposed average diversion on an annual basis at Northfield, would lower the stage by 0.2 feet at this location and by lesser amounts downstream. It is conjectured that this would not significantly affect the total quantity of

groundwater in the Connecticut River Basin (Farquhar, in press). The important question is what magnitude of diversion would produce measurable reduction in Connecticut River Basin aquifers? It is not possible to answer this question at this time."

Further reading of Berger's paper made me extremely skeptical with respect to further diversions from the Connecticut River and/or its tributaries.

4) Lack of information as to the environmental impact of construction and annual cleanup of spoils: On page 52 (line 25)and on page 108(line 3) you mention the need for stripping organic matter from Tully Lake and the need for disposal sites for the spoils created by tunnelling to Quabbin. Admitedly, the latter problem would develop only once, but the former could be an annual one. The draft E.I.S. however does not deal adequately with either of these problems.

5) Desalination as an alternative:

a) costs of desalinated water: On page 122 (line 18) you state that desalinated water "indicate costs in the vicinity of 73 cents per thousand gallons." This seems to me to be misleading, in light of the enclosed cost graph reproduced from the "North Atlantic Regional Water Resources Study (1972) Appendix R--Water Supply; Corps of Engineers, U. S. Army: p. 176.

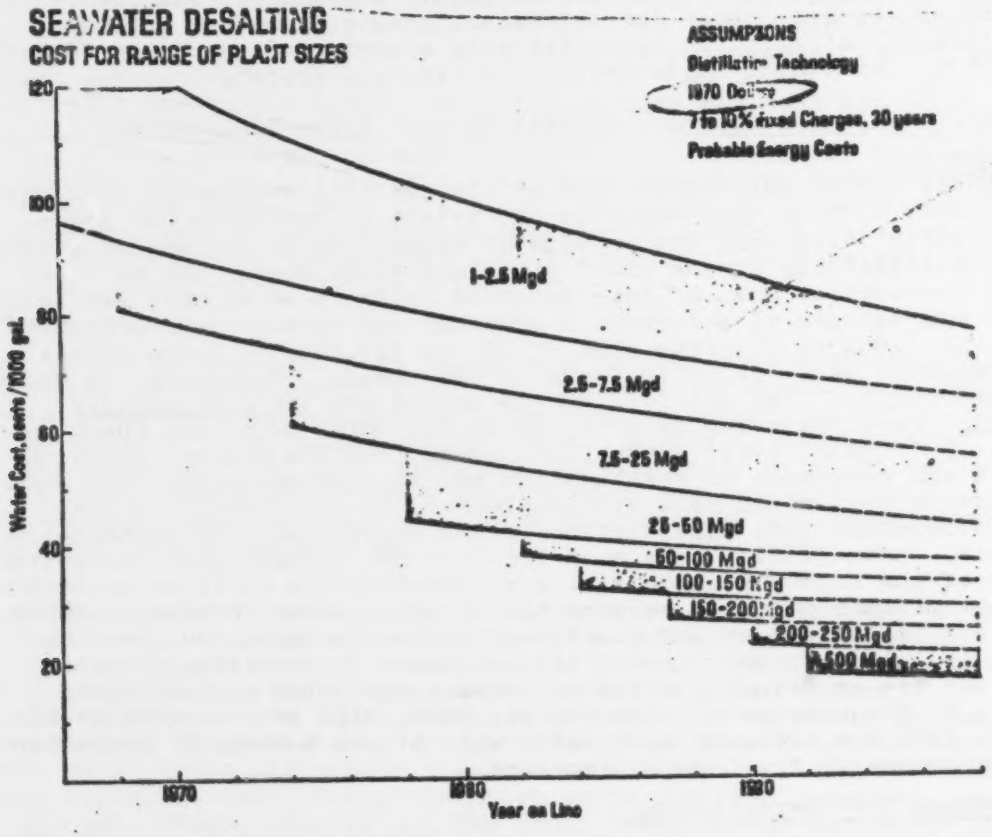

FIGURE R-35. SEAWATER DESALTING - COST FOR RANGE OF PLANT SIZES

Desalting sea water may, indeed , cost $0.73 per thousand gallons now, but before you estimate Quabbin will dry under a "do nothing alternative" the cost of desalinated water will be less than one-half of the figure you cite in the E.I.S..

b) Desalination as an alternative--It is apparent to me that the proposed diversions are no more than stop-gap measures (see page 63 and fold out sheet entitled "Estimated Demand on Quabbin-Wachusett System for verification of this observation). What is needed now is a bold new approach. As the North Atlantic Regional Water Resources Study, Appendix R, p. 157 has so aptly pointed out:

> "A significant aspect of desalting is its capability to provide a completely controllable new source of fresh water that isn't subject to the whims of nature. Furthermore, it is a source not complicated by many of the institutional constraints that often exist with inter-basin transfers or with local diversion. Its flexibility permits it to be located near the area of need, with units added as the demand increases. This permits it to be used as a firm supply, as an interim supply until large surface water systems can be put into operation, and as a conjuctive supply to increase the firm yield of an existing system."

With these words in mind as a possibility for solving the problems of the water-poor eastern end of the state, I completed the following documented research paper for the Massachusetts Executive Office of Environmental Affairs, in my capacity as a member of the Water Resource Task Force, appointed by Secretary Charles H.W. Foster.

Report to the Water Resource Task Force: 1972--Desalination

Introduction

Rubey (1951) has stated that of the juvenile outgasings from the earth, only 1.0% of this vapor is sufficient to replenish our geological water supplies. The problem of water then is not one of amounts but of availability at the right place and right time. Due to geological techtonics, most of this juvenile water is being made available to our hydrosphere at mid-oceanic trenches and tabular data presented by Popkin (1964:4) indicate that 97.2% (or 317,000,000 cubic miles) of our available water is to be found in the oceans. Therefore, it seems most appropriate that one look to the oceans and (if economically feasible) accelerate the water cycle to replenish dwindling fresh water supplies. Popkin (1969) enthusiasticly reviews the present state of the are and economics of desalination and also presents abundant data to refute a contention made by Hirshleifer, at al. (1960) for the RAND Corporation that desalination is not economically or technically feasible. Odum (1971), in a much briefer, but perhaps more thoughtful review of the problems associated with desalination cautions against over use of this means of solving all of man's water problems without prior ecological and social studies of the environment, but even he states (p. 419): "There is very little hazard in desalting of ocean water for use as drinking water in densely populated coastal urban areas..." The purpose of this report, then, will be to review desalination (and the problems associated with it) as a means of replenishing Massachusetts fresh-water supplies.

Other Meand than Desalination

Before proceeding with a discussion of the benefit/cost analysis of desalination, it seems appropriate to review briefly the other con-

templated sources of fresh water for Massachusetts' needs.

a) Surface water--One need not proceed far in the literature before realizing that this resource is being depleted at an alarming rate. Popkin (1969) estimates that on a global scale 0.01% (30,300 cubic miles) of the earth's hydrosphere is constituted as fresh water lakes, rivers, and streams, and with respect to our region's water supplies, the U. S. Geological Survey (Piper, 1965)--for New England in general--and the Army Corps of Engineers (NEWS, 1972)--for the state; specifically Quabbin Resevoir--estimate that before the year 2000, water may be in critical supply in this state if present consumptive patterns continue; the U.S.G.S. report, however, states that with wise use the supply problem may not be as great a crisis as the Corps contemplates.

b) Plans are rapidly reaching the implementation stage for the out-of-basin diversion of water from rich areas (eg., Western Massachusetts) to water poor areas (eg., Boston). However, as Kendeigh (1961), Keighton (1965), Benton & Werner (1966), Smith (1966), Odum (1971), Brower (1972), Chapman (1972), and EMLR (1972) collectively show, on both theoretical and practical grounds, of the importance to estuaries, of the flooding cycle, the plans for river diversions (in the absence of base-line data on the biology of specific estuaries) are unwarranted. Not only are diversions potentially damaging to the estuaries--the richest energy and food source in the world (Douglas and Stroud, 1971; NES, 1970; and NAR, 1971)--of the rivers from which these diversions take place, but also for in-basin citizens, out-of-basin diversions remove a resource (eg., potentially potable water) that they would find most difficult to re-obtain at a later date when these citizens require their own river waters for their own use.

c) Soil and Ground Water. This report does not deal with the feasibility of harvesting this resource, but as a result of surveying the tabular data presented by Popkin (1969:4) which indicate that only 0.62% (2,016,000 cubic miles) of the earth's hydrosphere is in this form of water, it seems, that as a long-term source of water, pursuit of this potential supply has world-wide limitations. Only a detailed study of Massachusetts sub-surface supplies will indicate to what extent these limitations apply in this state.

Desalination

As indicated earlier, this report was to deal with a discussion of the benefit/cost ratio analysis of desalination. It should be pointed out, however, before beginning that this discussion will be brief, as there is abundant literature already, on all phases of desalination (eg., see Johnson, 1970: and OSW, 1972, for abstracts of approximately 2000 technical papers and reports dealing with not only the state of the art of desalination, but also its social economic and ecological environmental benefits, and costs as well).

Benefits

At this stage in the history of Massachusetts' utilization of its water resources, there is a two-fold problem which at first glance doesn't appear to be related. The aspects of this problem are: supplies and distribution of potable water and disposal of solid wastes.

With respect to the first problem, growth of urban areas in the eastern part of the state long ago stripped their long-term reserves of fresh water which ultimately resulted in the construction of Quabbin Resevoir which was felt at its inception to be the final answer. Yet, as is now well known, this is not the case. NEWS (1972) estimates that already the existing system yield of Quabbin is being exceeded by the demand placed on this resevoir. Admitedly, a better conservation pro-

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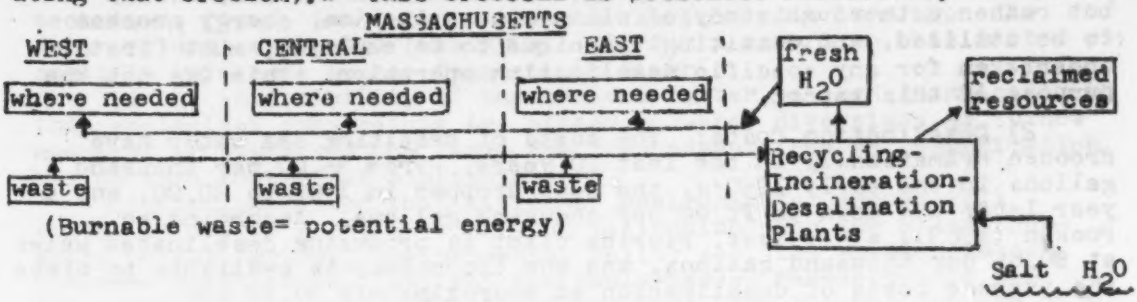
gram would alleviate the problem (Piver, 1965), but based on the history of human nature, wants or desires very quickly become needs which generate demands which can't very quickly be eliminated by convincing people that these so-called needs are unnecessary in the pursuit of the "good life". So, although an enlightened education of the public is essential in order to develop their continuing concern for a natural resource usually taken for granted (i.e., water), nevertheless, a program of accelerating the supply of this resource in a way least damaging to the environment is necessary. Desalination of sea water provides such a means, because (1) it fits more naturally into the geological water cycle than do other means of supplying potable water (eg., diversions from one river basin to another), (2)it provides for the control of fresh water supplies closest to the major and ultimate source of these fresh water supplies (i.e., the sea) and (3) desalination techniques fit more easily into the application of the law of supply and demand than do other techniques for supplying fresh water, in that under temporary high demand needs, more output can be sought to augment natural fresh water supplies, while when the demand is low, less salt water need desalinated. How the latter would be regulated would depend a great deal upon the economics of desalting larger vs. smaller amounts of salt water (see Spiewak and Ebel, 1967). Also, with saline technology proceeding so rapidly, it is evident that de-salting facilities can be constructed in an open space much smaller than a fresh water resevoir, and yet, in the long run, is likely to produce water at a far cheaper environmental cost and in larger amounts.

With respect to the energy necessary to desalinate sea water, a problem would appear to be in the offing--the well-documented energy crisis that this country is facing. Although many authors enthusiastically support nuclear energy as a source for desalination (see Johnson, 1970 for many references on this matter), nevertheless, there are questions in many reputable scientists' minds--including several Nobel Laureates with expertise in the field of nuclear energy (eg., Joshua Lederberg)--that this technology has not reached the stage of development where it can be depended upon to produce safe supplies of inexpensive energy. Yet, solid waste as a source of energy has been examined by many authorities (eg., Reichle, 1965; and Gitterman and Zgickler, 1966) and according to recent press releases, states are committing themselves to this "resource" (eg., Northeast Utilities, General Electric, Southern Connecticut Gas Co., the State of Connecticut, and the federal government have committed 1.2 million dollars to a solid waste disposal-energy generating project). Also, the town of Saugus, Massachusetts is planning an energy conversion plant capable of transforming the refuse of 16 communities including Boston and Lynn into commercially salable steam (EN, 1972:12). Massachusetts, with its solid waste disposal problem, rapidly filling sanitary land-fill sites, and increased expenses that other communities--eg., Westchester Co., N.Y. (Greenhouse, 1972)--are experiencing, using this technique of dealing with solid waste, can ill afford not to seek other, more environmentally sound, expeditious, economical, and efficient means of dealing with solid wastes.

Stickel (1972) has presented a proposal for combining desalination (as a means of solving fresh water supply problems) and the energy that can be generated from solid waste (as a means of elimin-

ating that problem).* This proposal is presented pictorially below:



Admittedly, the above is a bold step and a complete turn-around with respect to the direction that fresh water is now "flowing" (eg., present and proposed diversions of Connecticut River Basin Water) but there are precedents for such a scheme.

1) The well-known water cycle--from the sky: to the ground: to watersheds: to rivers: to the sea: and back to the sky. The above scheme would essentially do the same with the substitution of the recycling--incinerator--desalination plants for the sun as an energy source for moving water from the oceans back into the sky and pipes (substituted for wind currents) for moving water back into natural watersheds. With the critical need for rubbish disposal sites in Massachusetts, an incineration scheme as outlined above would solve this problem in one effort (and would keep Massachusetts' railroads alive too).

2) Such a desalination plant is already in operation at Hempstead, Long Island, New York.

Costs

The overall costs of desalination can be placed into three categories: 1) Plant Construction Costs, 2) Desalination Costs, and Environmental Costs.

1) Plant Construction Costs: It would be premature, at this time, to attempt to place a precise cost on plant construction. This does not mean that this information is not available (pers. comm. from Frank O'Shaunnesy, Division of Desalting Feasibility & Economic Studies

* Since the writing of the original paper, a feasibility study involving the use of energy from a refuse incinerator has been brought to this writer's attention. Kaiser Engineers. 1972. "Preliminary Engineering and Cost Assesment: San Diego Refuse Incinerator-Desalting Plant" prepared for the U. S. Dept. of the Interior (Office of Saline Water) and City of San Diego. Rept #72-26-RE. 36pp.; Costs per 1000 gallons of desalinated water =$0.60.

of the Office of Saline Water; ADL, 1972; and BLR and OSW, 1972), but rather a thorough study of plant site selection, energy process to be utilized, and desalting technique to be employed, must first be undertaken for any specific desalination operation. This was not the purpose of this report.

2) Desalination Costs: The costs of desalting sea water have dropped dramatically in the last 20 years. From $5.00 per thousand gallons in the early 1950's, the cost dropped in 1960 to $2.00, and a year later was down to $1.00 per thousand gallons. According to Popkin (1969), a Key West, Florida plant is producing desalinated water at $0.85 per thousand gallons, and the technology is available to place the average costs of desalination at approximately $0.50 per thousand gallons (pers. comm. from J.J. Strobel, Chief, Desalting Feasibility and Economic Studies, OSW). Others (Hammond, 1962 and GNEC, 1964) estimate the costs could readily fall to $0.15 to $0.18 per thousand gallons, depending upon the type of desalination operation.

3) Environmental Costs: The problem of dealing with brine wastes is a very valid one, and has been intensively studied (Thompson, et al., 1969: Zeitoun, et al., 1969 and Clarke, et al., 1970). Methods are being devised to prevent pollution of estuaries and other off-shore areas by desalination plants (Zeitoun, et al., 1969).** Also, AAPG (1971) and others (eg., Alverson, 1970) have intensively examined the potential for deep-well disposal of saline wastes. As Dr. Travers Hughes of the Geology Department, University of Alabama, Tuscaloosa, Alabama, pointed out in a personal communication, a thorough geological survey of potential disposal sites that are available must be completed before injection of any waste is attempted, but he feels that in the case of brine--a material with a chemical constituency similar to very deep water supplies--such injections would very likely have a self-sealing effect upon the wells utilized for such waste disposal.

Recommendations

As Johnson (1970:1441) pointed out in his Introduction to the Symposium, Saline Water, a Valuable Resource, "The rapid development of desalination technology has brought with it the recognition of a new intrinsic worth for saline water... and with it...among hydrologists and water resource managers, the recognition that...saline water.. actually could be a valuable resource." To me, it seems important for water resource managers with responsibilities for providing for Massachusetts water supplies to pursue detailed studies now, and to implement desalination techniques as soon as possible for the following reasons:

1) the obvious need for potable water

* According to Frank O'Shaunessy (pers. comm.) of the Office of Saline Water, United States Department of the Interior. The state of the art of desalination is such that $0.30 per thousand gallons is probably the lowest cost one can expect for desalinated water for the foreseeable future.

** Also, OSW has completed model studies which indicate that brine can be safely disposed of by diffusion into open oceans. (pers. comm., Frank O'Shaunnesy, Office of Saline Water, Dept. of the Interior.

2) the very real potential damaging effects that the present techniques (i.e., inter-basin water diversions) can have upon the donor rivers' estuaries (see EMLR, 1972 for a report on this matter wi specific reference to the Connecticut River).

3) the inflexibility of the present "water taking" techniques, in that ecological constraints are placed on water diversions as to how much can be taken and how large the impoundments can be; desalination has no such ecological limitations.

4) the likelihood that citizens' environmental groups will engage in costly and time-consuming litigation (for the state) pursuant to the National Environmental Policy Act, the Massachusetts Citizens Right to Sue Law, and the newly-passed Massachusetts Environmental Policy Act, if river diversions from the western end of the state are utilized as a solution to the potable water problems of the eastern end of the state.

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I am convinced more than ever that diversions should be downgraded as an alternative method of satisfying man's water needs. Desalination may not be the final answer, but it, along with ground water supplies, should be given far more attention in this age of rapid technological advances than inter-basin transfers.

In conclusion, I can say no more than to echo the following observation from the New England Research Incorporated Report (Vol. II, page 15):

> "Research on the environmental impact of projects is not to be used to justify decisions already made, but rather, the decisions are themselves to be influenced by research."

I would appreciate my statement being made part of the final environmental impact statement, and that I receive a copy of the final environmental impact statement.

Yours sincerely,

David W. Stickel

David W. Stickel,
1) Asst. Prof. of Biology,
Holyoke Community College
2) 1972 Water Resource Task Force for the Commonwealth of Massachusetts
3) Board of Directors, Connecticut River Ecology Action Corporation

Titan's Pier
South Hadley, Mass. 01075
27 December 1972.

John W. Leslie, Chief
Engineering Division, Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Mass. 02154

Dear Mr. Leslie:

The following comments on the Preliminary Draft Environmental Statement for the Northfield Mountain Water Supply Project and the Miller's River Basin Water Supply Project - Northeast Water Supply Study (DEIS) represent an extension of earlier statements made on 11 Jan. 1972 and 6 July 1972 on behalf of the Sierra Club, New England Chapter and the Connecticut River Basin Task Force.

The nature of the traditional method of obtaining drinking water for the Metropolitan District Commission's service area has unduly influenced the Corps of Engineers in its study of additional water supplies. When water has become scarce or when quality of nearby supplies has diminished, it has become customary for Eastern Massachusetts to move continually westward within the Commonwealth to seek more and better quality water. Because of an unbalanced population distribution within the state, Western Massachusetts with its relatively sparse numbers of people has fallen prey to the political pressures of the more populous Eastern sector. In the light of long-range planning and the present understanding of the limits to growth that any society must take into account, this headlong scramble for new, pure surface water for the M.D.C. must come to an end. The communities bordering the Connecticut River and its tributaries have need of the water within their own drainage basin. The State of Connecticut expresses increasing concern over the potential depletion of Connecticut River waters if the projected eight or more diversions which have been considered are put into effect. The diversions under consideration in the specific proposal at hand have within them the seeds of further diversions. It should be noted that citizens of the Delaware River Basin have sued New York City for diminishing the quantity and quality of Delaware waters (New York Times, 2 Nov. 1972). This is reminiscent of the Connecticut - Massachusetts suit over the building of the Quabbin in the first place, a case which could be reopened if detriment were shown downstream in Connecticut.

The mission-oriented focus of Corps' projects by its very nature precludes a full evaluation of alternative actions. For the Corps, under a "Congressional mandate," to perpetuate an existing State pattern of water-grabbing from its less populated areas seems basically wrong.

Interestingly, a part of the proposed study had spurious origins.

The idea for the Northfield diversion came from a utility executive seeking multiple justifications to gain a license from the Federal Power Commission for a pumped storage facility using the Connecticut River as a lower reservoir. The M.D.C. was approached by the utility, saw the potential of Northfield pumps for adding Connecticut River water to the Quabbin supply, and took over the diversion plan. This, then, fell to the Corps under the NEWS study in a secondary way.

The ultimate economics of the Quabbin as the distributing reservoir system for the Commonwealth is questionable. Will Holyoke, Northampton and Amherst, for example, end up drinking Connecticut River waters which have been pumped to Quabbin and back ? It would seem that diversification with the development of alternative sources of supply should be undertaken for several reasons.

1) For the public health and safety, it is important to have alternate sources which can be drawn on should one source become contaminated for a period of time. Surface water is particularly susceptible to pollution from airborne wastes or chemicals that may enter the supply. It is worth noting that in a statement prepared by Western Mass. Electric Co. for the Turners Falls dam, that the Turners Falls pool from which Northfield pumps, contains phenols from "0.0002 to 0.0004 ppm, well below toxic levels to fish but potentially capable of imparting an unpleasant flavor when combined with chlorine". (pg.62). And also, it is stated in the same place that " copper (up to 16 micrograms/L), lead (up to 108 micrograms/L) and zinc (up to 60 micrograms/L) exceed levels considered 'safe' by some biologists". It should furthermore be noted that the Miller's River will at times be drawn upstream by the pumping up of water through the Northfield pumped storage intake. Miller's water is rated unsatisfactory to D quality now, but is expected to improve to B within five years. Should Northfield operate as a diversion source prior to the cleanup of the Miller's River, potential contamination of the Quabbin ought to be considered.

2) Changing economics resulting from improved technology, and periodic reassessment of priorities should be factors in weighing alternatives. As the study stands, all the alternatives except the proposed projects are rejected. For example, however, as desalinization is becoming more economical, its feasibility ought to be investigated simultaneously with other alternatives, not separately at a later time when a decision on water diversion has already determined a course of action. Or in another instance, if production of protein food becomes a high priority in the next few years, the use of the Connecticut River for out-of-basin water supply could preclude adequate seafood production in the Connecticut River estuary. The Connecticut Basin diversions, it is claimed, would take only waste waters by flood skimming. This is not so because the natural fluctuations in river flow are a part of the evolutionary sequence basic to life in the river and its estuary. The time scale for change is in millions of years and man is a newcomer to an ancient system. (Speaking of 50 years as long term planning is naieve). Flood waters are necessary to the salt:fresh water balance in the estuary where during the

annual flood cycle important breeding grounds for shellfish and marine fish occur. Furthermore, the success of the entire anadromous fish restoration program depends on the excess flow of fresh water out of the mouth of the Connecticut River in late springtime.

3) The importance of developing ground water supplies has been badly under-emphasized. If Plymouth Co., or elsewhere, proves to have large reserves, the superficial preservation of a few recreational ponds is not adequate reason to ignore a pure, self-cleansing, and renewable (with proper care) source. Ground water development should be pursued actively now and recharge areas mapped and protected from imperviousness due to construction on top or other misuse of the sites.

4) The use of Quabbin waters for flushing purposes should be re-examined for the Chicopee River and the Charles River, or others, where this is practiced. Point sources of pollution should be attacked and cleaned up, such as Monsanto on the Chicopee. Flow regulation (as distinct from low flow augmentation) on the mainstem of the Connecticut River should be fully instigated at the 0.2 csm level, or as recommended by the State Division of Fisheries and Game and the Federal Bureau of Sport Fisheries and Wildlife. If the mainstem is regulated for an instantaneous, minimum continuous flow, then the Chicopee can be managed more frugally so as to let less Quabbin water go by to adjust levels at Hartford. This pertains solely to the existing Quabbin waters, for it should be clear that additional out-of-basin diversion is and has been (see our statements of 11 Jan. and 6 July 1972) unacceptable.

5) A reorganization of priorities within the M.D.C. is urged. The South Sudbury and Cochituate reservoirs and the Sudbury River should be cleaned up and used in the system. It is not right to use what was once drinking water for recreational purposes for some local residents, while penalizing residents in another part of the Commonwealth by diverting their water into a different drainage basin.

6) Finally the concept that what is good for Boston is good for the Commonwealth should be reconsidered. In the light of our present knowledge, it is unrealistic to think that material growth can persist indefinitely at the rate it has been, much less at an increasing rate. This involves the use of all natural resources, including water. The problem is, in part, one of public education. If the Corps can not assume this responsibility, then the Commonwealth must do so. To speak of brown lawns and depressed suburbanites is playing ostrich to the basic problem of the limits to growth. The reclamation of waste waters, water rates to encourage conservative use, water rationing, repair and replacement of poisonous lead piping (causing water to be run at the request of officials and thereby wasted), use of less-than-drinking quality water for industrial purposes and fire protection, revamped domestic plumbing systems, frugal use of air conditioning, and other such practices must become a part of the system.

Educational field trips by bus to the Quabbin should be introduced into the schools of the M.D.C. service area so that every child comes to appreciate the tax on the environment that water use represents. It doesn't just come out of the pipe, it comes out of the Connecticut River Basin ecosystem, and it is a resource given that is in no way paid for, if one speaks of donors and receivers.

What the Connecticut Basin has to give as the best agricultural region in New England and a recreational area with the potential for a great salmon and shad sport fishery, should be carefully weighed against bleeding the Basin as a water supply. Reduced fertility of now rich floodplain soils and reduced life in the waters of the River and its estuary will be the result of continued out-of-basin water diversions.

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Proposed Report of the National Water Commission, Chapter 8: 1-33. (It will be seen that arid regions have been primarily involved; we feel that other alternatives than water diversion should be fully examined for the New England region).

Sincerely yours,

Jane Van Zandt Brower.

Jane Van Zandt Brower, Ph.D.

Chairman, Connecticut River Basin Task Force; Member, Executive Committee New England Chapter, Sierra Club.

APPENDIX B

PREFACE

This Appendix summarizes the steps in the final preparation of the Impact Statement. It includes the coordination at the Washington level with Federal Agencies and the State and responses to their comments on the Draft Environmental Statement. Responses to their comments are grouped according to these agencies. There were also comments on the Main Report of the project - these are indicated where applicable in this Appendix B.

Future efforts aimed at improving the quality and quantity of environmental data available to management with responsibility for planning and developing this project should adequately resolve most of the questions raised by the agencies whose comments are included in Appendix B.

U.S. ENVIRONMENTAL PROTECTION AGENCY

Comment - The proposed aqueduct may be a point source discharge into Quabbin Reservoir which requires a NPDES permit. Our General Council's Office is in the process of making a determination. During preparation of the Final Impact Statement, our offices should work jointly to resolve this question.

Response - As the Final Statement was being prepared, proceedings were still underway to resolve the question of a permit. Recent correspondence has indicated that a permit will probably not be necessary.

Comment - The high quality of the drinking water in the Quabbin Reservoir necessitates a continuing and effective water quality monitoring system. Also, provisions for water treatment should be included in the long range plans.

Response - During the advanced engineering and design stages specific scheduling and a design of a monitoring program will be developed. At this time the requirement for necessary water treatment will also be determined.

Comment - The "best practicable treatment" of upstream wastewater which is recognized as being required in the Draft Statement may not provide the consistently high quality of water needed for diversion to Quabbin Reservoir. This can only be determined after plants are in full operation and an extensive water quality monitoring system is established as indicated in the Draft Statement.

Response - We agree that the project as proposed requires information which will be available only after treatment facilities are in operation.

Comment - The Draft Statement mentions the possibility of a "Y" connection in the tunnel aqueduct to Quabbin Reservoir. We feel the provision for full diversion of the flow to either the west or middle branch of the Reservoir would guard against possible short circuiting of the system. The Final Statement should more completely discuss the "Y" connection and make a more positive statement as to whether the "Y" is part of the proposed plan.

Response - As discussed in the report and in earlier agreements at meetings held with EPA officials, it was decided that the "Y" connection may be necessary. However, the actual need for the "Y" connection would be dependent upon water quality condition within the Connecticut River and Quabbin Reservoir during the period that the project is being designed.

U.S. DEPARTMENT OF INTERIOR

Main Report - Millers River Basin Water Supply Project

Comment - The project's proponents should indicate precisely where and what minerals occur and their relationship to the project. If any minerals are found or located in the project right-of-way, the project proponents should so indicate and give some estimate of the extent to which future recovery of these minerals will be affected. A map locating the known mineral resources in relation to the project vicinity would allow easier assessment. Any minerals preempted by the project

should be described in the section "Irreversible and Irretrievable Commitment of Resources".

Response - The sand and gravel deposits described on Page 14 are the predominant mineral resources within the Millers Basin. Although peat and miscellaneous deposits also exist, they are not considered to be typical deposits which would be mentioned in this background type section.

The majority of the projects' facilities would be deep rock tunnel aqueducts. The geology of the tunnel routes is given in Appendix E to the Main Report. It is not anticipated that the tunnel construction would hinder further mining efforts.

Comment - The Millers River Basin fish habitat resources have not been adequately described on Pages 14-15. The anadromous fish restoration potential should be noted. The impact of diversion on this and improved resident fisheries resources should also be recognized and evaluated.

Response - The description of the Millers River fish habitat resources is considered adequate for the purposes of this background information section. Whereas the basin is not currently being contemplated for Atlantic salmon restoration, reference to future use of the basin for such purposes would be misleading to the reader.

A description of the impact of diversions on the existing and planned fisheries resource is included in Section IX, Project Impact Analysis. In addition, the control flows used in the operational procedure for the project was developed by U.S. Fish and Wildlife

personnel and these were intended to minimize any impacts of the river's environment including the fishery.

Comment - A description of the environmental setting and natural resources of Quabbin Reservoir should be included in Section 6 of the main report.

Response - Appendix I of the report described Quabbin Riservoir in some detail. The evaluation given in the main report refers to this appendix and the data contained therein.

Comment - Control flows for the Millers River Basin diversions are presented as finite on Pages 61 and 66, but Fish and Wildlife Service understood that they were set at "best estimates" for planning. This should be clarified in the main report, as well as noting that leeway exists for adjustments as environmental considerations warrant.

Response - The control flow estimates shown on Pages 61 and 66 are indeed estimates prepared by the U.S. Fish and Wildlife Service under contract to the Corps of Engineers. Since a considerable amount of effort and money was expended in determining these figures, it is unclear as to why any significant variations should be expected.

Comment - Pages 144-145. The adverse fish and wildlife habitat impacts from pool fluctuations and erosion at diversion sites in the Tully complex are not addressed. It should discuss the loss or vegetation, silting of streams, restrictions to fish movements, turbidity and other impacts.

Response - Pages 144-145. The information given on pp 140-145 describes the effect on the area from the impoundments. Later on pp 156-157 the impacts of the Tully Complex alternative are discussed relative to the other Millers River Basin alternatives. In this discussion, the Tully Complex is described as having the most impact on the environment and is not the plan selected for implementation. The detail included in the discussion, therefore, was considered adequate for purposes of the report.

Comment - We recommend that the necessity for further studies presented in Appendices I and J be recognized in the Main Report, under the "Summary Conclusion" section.

Response - The studies discussed in Appendix I were initiated independently by the Metropolitan District Commission (MDC) prior to the completion of the subject study reports. The followup investigations recommended in Appendix J are primarily, as stated in that appendix, for information "which will be required as future demands arise for new uses of the river", i.e., actions beyond the subject report's projects. The Appendix J investigations recommended as part of the subject report's projects are a monitoring program and a hydraulic model of the river. The necessity for this program is described in both the Northfield Mountain and Millers River Basin reports in the section titled Description of the Project. The hydraulic model discussed will be constructed as part of the ongoing Massachusetts water pollution control program for the Millers and Connecticut Rivers.

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Comment - If fiscal and/or temporal constraints combine to delay the timely implementation of PL 92-500 (The Water Quality Act of 1972), water quality conditions may require that Connecticut River water be treated prior to diversion to Quabbin Reservoir. This differs from what was stated on Page xviii, Paragraph 2. Also, Page 57 of the Revised Draft Environmental Impact Statement notes, however, that the MDC plans to chlorinate diverted waters prior to their entry into the Quabbin Reservoir.

Response - There is no information available to us that indicates the scheduled improvements to water quality required under Public Law 92-500 have been modified.

Comment - Page xlv - on the statement "Studies should be conducted to determine .... the size of needed long-range water supply developments", it appears that conclusive evidence already exists to verify the need for measures to conserve and moderate water demand. The effect of any single conservation or demand moderation measure may indeed be insignificant, but the combination of several measures could have a sizable impact on the total water supply.

Response - On the question of conservation measures, the study reports recognize the need for further studies into the possible utilization of these techniques. Such studies would be conducted during the advanced engineering and design phase if the projects are authorized.

Comment - The "Recommendations" section (Pages 182-184) of the report

fails to include recommendations for further environmental impact studies listed in Appendix E, Page 121, Volume III. We recommend these studies be listed in the main report.

Response - The recommendations section does not include the Appendix E recommendations for further study because as in the Millers River Basin report these recommendations pertain to "future demands", i.e., actions beyond the Northfield Mountain project.

Comment - Although the report discusses the probable effects of water diversion on the donor and receiver water systems, it does not address the expected cumulation of synergistic environmental effects of existing and planned power production, flood management, irrigation, industrial cooling and domestic water supply plans as related to water diversions. A consideration of the cumulative effects of water use on the donor riverine system should be included.

Response - The Northfield Mountain project, as described in the report, is an element of the 1980 Connecticut River Basin Plan recommended by the Coordinating Committee for the "Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin". This study which considered water quality, power, outdoor recreation, anadromous fisheries restoration, resident fish and wildlife, water supply, navigation, upstream water and related land resource potential and flood control, had as one of its committee members, the Department of the Interior.

Environmental Impact Statement

Comment - The discussion of environmental impacts caused by construction makes no mention of the impacts or adverse effects on the existing or potential recovery of mineral resources in the project area. If this cannot be accomplished, a statement to this effect should be included in the Revised Environmental Statement.

Response - As noted in response to a 1972 comment on the Impact Statement we have included a general description of the geology of the region. This description was drawn from available data.

Comment - Because the project area is within Seismic Zone 2 where moderate damage can be expected, the Statement should discuss the possible effects of earthquakes.

Response - Advanced engineering and design considerations would include the possible effects of earthquakes on the project.

Comment - There is no discussion or adequate concern given to the protection of cultural resources, including archaeological values. Such commentary should be displayed in the Appendices and discussed in appropriate places in the text. In order to evaluate the magnitude of the affects on archaeological values, it was suggested for the Corps to consult qualified archaeologists as Dr. Maurice Robbins of Bronson University, or Dr. Dena Dincause of University of Massachusetts immediately, as well as with the State Historic Preservation Officer. Their commentaries should be displayed and discussed in the Environmental Statement.

Response - Federal regulations on historic and archaeological values

were not as well defined during the study period as they are today. During the next level of planning the cultural and archaeological resources which may be affected by the project will be given further consideration. As noted in the Draft Statement, the State Historic Officer was contacted and advised us that no known sites would be impacted. Also the National Park Service was notified and they did not respond with any known historical or archaeological sites which may be affected.

Comment - Paragraph 2, Page 83, Line 7 - the second alternative is a combination of one and three is inaccurate and misleading. It would be more accurately described as combining Alternative One with an element of Alternative Three (the East Branch Tully River diversion).

Response - Agree.

Comment - Pages 40-45, biological resources of the Millers River Basin are not adequately described. A potential for Atlantic salmon restoration exists, and the impact that Millers River Basin diversions would have upon it should be recognized in appropriate sections of the Final Environmental Statement.*

Response - This is essentially the same comment which was responded to in the Main Report, Comment #6. As noted earlier, the description of the Millers River fish habitat resources is considered adequate for the purposes of this background information section. Whereas the basin is not currently being contemplated for Atlantic salmon restoration, reference to future use of the basin for such purposes would be misleading to the reader. *See also Federal Power Commission, April 14, 1976, Comment #1.

Comment - Pages 40-43 - it does not consider the impact upon the improved fishery resources following pollution abatement.

Response - This impact is discussed on Page 64 of this Statement.

Comment - Page 40, Paragraph 3 - last sentence should be corrected to show that pleasure boating, as such, is not permitted on Quabbin waters.

Response - The word pleasure boating was not used in the report. The word regulated was used in front of boating indicating that the boating activity was governed by a permit system administered by the Metropolitan District Commission.

Comment - Page 57, paragraph 2 - the MDC plans to chlorinate diverted waters prior to their entry into Quabbin. The statements concerning this reflect the considerable concern for Quabbin's water quality if diversions are made from the Connecticut and/or Millers Rivers. Alternatives to chlorination should be examined, with one being ozonation. Advantages for ozonation include a lower potential for accidents related to use of chlorine and availability is not dependent upon market conditions. When the cost of ozonation is compared to the cost of chlorination, the benefit/cost ratio is highly in favor of ozonation.

Response - Alternatives to chlorination will be examined in the advanced engineering and design phase. Included in this alternative will be chlorination and ozonation as well as other possible treatment techniques.

Comment - It is recommended that Table 7, Block 4, Page 60 be modified

to show that fish species were intended to be designated under the heading: Introduction of Undesirable Species, as on Page 53 it was stated that undesirable algal species will be introduced.

Response - The table headings were meant to be all inclusive, and not limited to fish.

Comment - On Page 64, it is indicated that diversions "may shorten the (canoeing) season during lower flow periods in the late spring." This should be clarified as to the project operation and resulting impacts.

Response - It is felt that the description on Page 64 of the statement, which discusses impacts on canoeing in the mainstem of the Millers River, presented enough information at this level of planning for the reader to make a judgement.

Comment - We are concerned about the impact of water diversions on existing and potential recreation values, especially impacts which may occur during the major recreation use season. The proposed diversion dam will be a physical barrier to passage on the river and will effect flows in the river. The Statement should discuss measures that will be taken to minimize adverse impacts on the use of the river for recreation purposes.

Response - The diversion period for the project would be during high flow periods, which does not coincide with heavy recreational use of the river, except for the possibility of white water canoeing. The impact on canoeing is described on Page 64 of the Statement.

Comment - Page 94, Paragraph 5. Adverse fish and wildlife habitat

impacts resulting from pool fluctuations and erosion at diversion sites are not addressed. It should be noted that the extreme fluctuations during the growing season would adversely affect both terrestrial and aquatic vegetation and also the fish and wildlife utilizing these plants for nesting, escape cover and/or food.

Response - In the Main Report, the information given on Pages 140-145 describes the effect on the area from the impoundments. Later on Pages 156-157 the impacts of the Tully Complex alternative are discussed relative to the other Millers River Basin alternatives. In this discussion, the Tully Complex is described as having the most impact on the environment and is not the plan selected for implementation. The detail included in the discussion, therefore, was considered adequate for purposes of the report.

Comment - Page 113 - Diversions from the Merrimack and other sources to extend the water supply from the Northfield and Millers River diversion are presented. It is not clear in the order in which these diversions would be implemented. The order should be clarified and if these diversions are to be instituted in a stepwise progression, the need for each project should be reviewed prior to implementation.*

Response - The descriptions regarding possible diversions from the Merrimack and other sources are given to present alternatives to the Northfield Mountain and Millers River projects, not to replace these projects. As the Northfield Mountain and Millers River Basin projects are constructed, the majority of the eastern Massachusetts water supply needs will be met until almost the turn of the century. This allows time

for new techniques and pollution abatement which would influence the choice of projects, both Northfield Mountain and Millers River. *See also New England River Basins Commission, April 16, 1976, Comment #4.

Comment - Page 134. The statement "No known endangered species of birds or animals listed by the Fish and Wildlife Service utilize the proposed project lands.", should be revised. The short nose sturgeon (Acipenser brevirostrum) has been collected in the vicinity of Montague, and the Quabbin Reservoir land area contains a site as a potential location for future reintroduction of the American peregrine falcon (Falco peregrinus anatum). Both of these are on the "Endangered Species" list. It is recommended that the planners should consult with the Peregrine Falcon Recovery Team during the planning processes. From a review of the status of the bald eagle from the Department of Fish and Wildlife Service, it is considering the potential for including those bald eagles which frequent New England on the "Endangered Species" list. Representatives of the southern bald eagle migrate into New England during the non-breeding season; hence the present status review and potential for extension of the listing to include birds in the project area. Future Environmental Impact Statements should include a discussion of endangered plant species affected by project implementation.

Response - At the time the study was made the original statement held true. We anticipate as further studies are made by Fish and Wildlife Service additional birds, plants and animals may be added to the list.

We expect the coordination with the Fish and Wildlife Service will continue on this program when planning on the project progresses to the next stage.

Comment - Diversions from different river systems would provide significant additional water supplies to the MDC service area. While tapping one area to provide a resource required by another may solve the immediate problem, the ecological ramifications are likely to increase as additional supplies are needed. There is a need to study further means of lowering existing trends in water demand.*

Response - See response to Department of Interior, Comment #8.

*See also New England River Basins Commission, April 16, 1976, Comment #1.

DEPARTMENT OF TRANSPORTATION - U.S. COAST GUARD

Northfield Mountain Water Supply Project

Comment - The cost of improving the water quality in the Connecticut River at Northfield should be included in the cost of the project.

Response - Improving the water quality in the Connecticut River is required under Public Law 92-500. This Federal law mandates that the river be cleaned up regardless of whether or not the project which is the subject of this EIS is constructed.

Comment - Because the ability of the existing distribution conduits and aqueducts to handle the increased service is questioned, the cost of improving the present MDC distribution system to handle the additional water made available should be included.

Response - An analysis was made of the primary transmission aqueduct from Wachusett Reservoir into the Boston Metropolitan area. On the basis of this analysis, it appears some operational changes would be necessary to allow the system to meet its maximum demand through 1990.

Comment - "A preliminary contingency plan to protect Quabbin Reservoir in the event of an industrial mishap at an upstream papermill or an upstream oil spill on the Connecticut River would be highly beneficial to evaluate the potential consequence of the project."

Response - Design of a water quality monitoring plan would be included in the advanced engineering and design phase. Included in this program would be development of a contingency plan as suggested. In the case of the Northfield Mountain project, for example, no pumping of river water would take place if deleterious material were present in the water.

Comment - All available reasonable alternatives have not been mentioned in the report. The use of the Charles River and the Mystic River are not mentioned.

Response - The water supply setting, included in the statement, did discuss the potential of developing locally available supplies.

Comment - No mention is made of the existence of groundwater potential in communities presently served by the MDC.

Response - This is true, the reason being that the report centered on major known groundwater supplies, i.e., those which could meet the demand defined by the study. Both local surface and groundwater

sources were investigated to determine the role they might play in meeting the region's future needs.

Comment - In the section on alternatives, a condensed version of the University of Massachusetts report on "Water Usage in Communities served by the Metropolitan Commission" should be included.*

Response - The Council on Environmental Quality's recent guidelines requested that reports, voluminous inventories and similar data not be included in the Environmental Impact Statement, but be available at the sponsoring agency's office. Briefly, the University of Massachusetts report intimated that a large amount of unaccounted for water is leaking from the City of Boston distribution system. That the water is unaccounted for is concurred in but the conclusion that the water is leaking is not. Follow up work to confirm or refute the report's findings is currently underway. *See also New England River Basins Commission's April 16, 1976, Comment #6.

Comment - It is hoped that the Final Statement would have a section dealing with potential population redistribution, if any, from the Boston area to the central areas of Massachusetts if the proposed project is not implemented.

Response - The state of the art regarding a linkage between water supply projects and population-economic distribution is not clearly defined at this time.

Main Report

Comment - Section IX of the main report, and Appendix F were difficult

to understand as to the criteria for forming the ten community clusters. If all the towns in each cluster are implied to be similar, we totally disagree with the clustering and suggest rewriting the section. We fail to understand how a town like Weston where the average house is valued in excess of $90,000 is a moderate income area.

Response - We have reviewed the cluster within which Weston falls, and our studies indicate that the other included communities are similar in composition.

Millers River Water Supply Project

Comment - Some mention of the possible secondary effects of this action on the area should be included as Section H of the report points out how the project will promote recreational use of the waters in the area. Such effects as possible increased auto traffic from outside the region to use the recreational facilities should be mentioned.

Response - The possible secondary effects of increased use brought about by the project would be included as an area of investigation when firm recreational proposals are developed.

Comment - The Statement should show why the Millers Project cannot be implemented without the Northfield Project being implemented.

Response - The Millers River and Northfield Mountain projects are independent actions which can proceed by themselves. Estimates of future water demand through 1990, however, indicate both projects would be necessary.

Comment - A preliminary contingency plan to protect Quabbin Reservoir in the event of an industrial mishap or oil spill on the Millers River would be highly beneficial to evaluate the potential consequence of the project.

Response - See response to U.S. Coast Guard, November 5, 1975, Comment #3. Same basic response applies to Millers River Diversion.

STATE OF NEW HAMPSHIRE - Water Resources Board

Comment - We have not reviewed the project since it does not involve any interests within our jurisdiction in the State of New Hampshire.

Response - None needed.

STATE OF VERMONT - Agency of Environmental Conservation

Comment - In reference to the two proposed reports of the Chief of Engineers on Northfield Mountain and Millers River Water Supply Projects, Massachusetts, the State of Vermont does not desire to comment.

Response - None needed.

THE COMMONWEALTH OF MASSACHUSETTS - Executive Department

Comment - We anticipate that the reports will be well received by Congress, and that the Corps will receive the necessary funding to pursue its work on these important projects.

Response - None needed.

Comment - We wish to acknowledge the conclusion of the Chief of Engineers and the Board of Engineers that a formal agreement between the State of Connecticut and the Commonwealth of Massachusetts need not be a prerequisite to further Corps' involvement in the project.

Response - None needed.

Comment - We understand that the proposed reimbursement arrangements will be in accordance with the Water Supply Act of 1958. Upon completion of engineering and design work, the Commonwealth will be prepared to consider the matter of assurances, and to explore the legal and financial issues regarding expansion of the Metropolitan Water District.

Response - None needed.

FEDERAL POWER COMMISSION

Comment - There is no discussion of the fish passage facilities planned at Turners Falls or the effects of the proposed diversion on the later planned reintroduction of shad and Atlantic salmon runs above the Turners Falls Project. Recent fisheries studies at the pumped storage project by Massachusetts should help identify problems of fish protection, such as the hazards of anadromous and resident species being drawn through pumps, in order to revise this discussion in the Draft Environmental Statement.*

Response - At the time of the study in the early seventies it was unclear that fish passage facilities would be placed at Turners Falls. We have reviewed the suggested report and did not find enough pertinent information to include in this report. However, this information and

further information which may be developed in the interim will be used as a base to proceed with studies during the advanced engineering and design stages. *See also U.S. Department of the Interior, October 29, 1975, Draft Environmental Statement Comment #6.

Comment - There is no discussion of the impacts of the generation of electrical energy needed to pump the water for the proposed water supply project from the Connecticut River to the Northfield Mountain upper reservoir.

Response - At this stage of planning there is no indication that the project would have a major impact on the region's generating capacity. The reason being that the electrical generation during off-peak period when demand is normally low will be the electricity used for the pumping. Therefore we do not discuss the impacts as they could not be determined to be a significant action.

Millers River Basin Water Supply Project

Comment - Review by the Commission staff indicates that the proposed project would not be adaptable to the economical development of hydroelectric power. The project apparently would not significantly affect power production or the transmission of electric power or natural gas.

Response - No response necessary.

Comment - A number of hydroelectric power plants, many licensed by the Commission, are located on the Connecticut River downstream from the confluence with the Millers River. A discussion of the effects of the proposed diversion of flood flows from the Millers River on these

plants should be included in the report and the Draft Environmental Statement.

Response - Because diversion will take place during high flow periods, flow remaining in the Connecticut River after diversion would be greater than flow capacity of the existing downstream stations.

NEW ENGLAND RIVER BASINS COMMISSION

Comment - An addition of 78 million gallons per day (mgd) by 1990 and 141 mgd to the water supply of communities served by the Metropolitan District Commission (MDC), is predicted by the Southeastern New England (SENE) Study and the Northeastern U.S. Water Supply (NEWS) Study respectively. Timing and the need for more research on alternatives to and impacts of the Millers River project make this an important difference. With respect to alternatives the SENE Study would give greater emphasis to conclusions that accelerated research should be carried out regarding (1) pricing as a means of water demand management, (2) public education as a means to encourage water conservation, (3) the cost-effectiveness of water saving devices, and (4) elimination of health hazards in recycling wastewater for domestic use. The potential of industrial recycling of wastewater and changing the rate structure for high volume water users so as to increase publicly supplied water for domestic use should be emphasized.

Response - Many of the comments on the reports are created by the adoption of certain assumptions in the Southeastern New England

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(SENE) study which differ from those used in the Northeastern Water Supply (NEWS) study. For example, the demand projections developed by SENE estimate only an eleven million gallons per day (MGD) increase in the Boston Municipal demand for the period 1970-1990. This limited increase shown by SENE is in marked contrast to past trends within the city. In fact, during 1975, Boston used as much water as SENE has estimated for 1980. Use of the SENE estimates, based on Boston's experience, could prove to be a lower limit of future needs. We believe conclusions drawn from these forecast demands regarding project selection and implementation must be somewhat guarded. Both the NEWS and SENE studies recognize the need for wise use of our valuable water resources. In this regard, both investigations made recommendations as to the need for further study into water conservation measures, and we see no great difference in the report findings. In fact, the item pertaining to the recent water usage study prepared for the Metropolitan District Commission (MDC) noted in your letter, refers to a study prepared as part of a joint MDC-Corps' effort to determine current usage patterns such that appropriate conservation measures could be directed toward areas of need.

Comment - The SENE Study recommends increased research into the techniques of economically feasible, environmentally safe desalination as a long-range method of meeting Southeastern New England's water needs.

Response - With regard to desalting there appear to be no conflicts

between the SENE recommendations for increased research and the conclusions drawn in the Impact Statement. Reference is made to pages 101-105 discussing the potential of desalting as a supply source for the region.

Comment - Unlike the NEWS Study, which rejects to the Plymouth County ground water as a possible alternative source of water for the MDC on the basis of its cost, the SENE Study has found that most of the Plymouth County supplies would probably be needed to meet local, in-basin needs. This finding is also consistent with the SENE Study's overall principle of encouraging local use of water supplies over interbasin transfers.

Response - There does not appear to be a conflict between the SENE report, which recommends local use of Plymouth County groundwater, and the conclusions given in the Impact Statement on pages 108-113.

Comment - Problems of poor water quality in the Merrimack River and the expense of its treatment lead both the NEWS and SENE studies to view this source of supply only as a long-range alternative to meet the MDC needs, and the SENE Study endorses continuing study of this option. Again, the implications of interbasin transfers will have to be considered.

Response - It is agreed that the implementation of interbasin transfer of water in tthe Merrimack River will have to be seriously considered in future planning to meet the long term water needs of the Eastern Massachusetts area. See also U.S. Department of the Interior, October 29, 1975, Comment #14.

Comment - The NEWS Study has stated that development of a diversion from the Sudbury River would be fully compatible with the projects. If the MDC estimate of an additional 40 mgd being made from this source in the near future is correct, this, with the water from the Northfield Mountain diversion, could be sufficient to meet the 1990 needs as projected by the SENE Study. This could affect the timing of the Millers River project.

Response - The potential of developing the Sudbury River is included in the EIS. As described in that statement it is estimated this increment could cost about twice that of the Northfield Mountain or Millers River water.

Comment - A recent study, prepared for the MDC by the Water Resources Research Center at the University of Massachusetts and Curran Associates, Inc., reports that if leaks and breaks in the MDC communities distribution systems, which exceed 3,000 gallons per mile of main per day, were corrected, 47 mgd or more might be saved. The findings of this report should be investigated and verified.

Response - See Coast Guard Comment #6.

Comment - The Commission's 1980 Connecticut River Basin Plan recommends that all diversions from the basin be conditioned on water quality monitoring and recognition of the basin communities' right of return of these waters when needed for water supply or flow augmentation. The Millers River project and other diversions are recommended only if certain conditions are met: (1) establishment of water allocation

mechanisms giving downstream states a voice, (2) prior evaluation of economic, environmental and social impacts, (3) continued water quality monitoring, and (4) determination of the adequacy of Connecticut Valley groundwater resources. The SENE Study predicates its approval of the Northfield Mountain and Millers River projects on the fulfillment of the Plan's conditions.

Response - As stated, the SENE recommendations are qualified as they are predicated upon certain conditions discussed in the 1980 Connecticut River Basin plan. The plan formulation for both Millers River and Northfield Mountain was conducted with full knowledge of the 1980 plan.

Comment - The Chief of Engineers states it will not be necessary to stipulate the establishment of an agreement between Massachusetts and Connecticut on the diversion issues as a condition for Federal participation. However, the Board of Engineers for Rivers and Harbors, in giving reasons warranting Federal participation in funding the project, has given reasons which show the necessity of an agreement between the states. The statements include the following:

"The project would have interregional and interstate impacts (emphasis added);

"The project(s) involves regional equity issues" (emphasis added);

"The project(s) involves resolution of interbasin water transfer issues" (emphasis added).

The Federal Government should require that the two States establish a mechanism to allow downstream interests a voice in water supply allocation.

Response - The question of the requirement for a regional mechanism prior to participation by the Federal Government in the projects was discussed by the Board of Engineers for Rivers and Harbors. The Board was convinced that "resolution of any jurisdictional claim associated with the project can be approached best through the mechanism of requiring local assurances to hold and save the United States free from water rights claims rather than stipulating specific their sovereign prerogatives." Although we understand your concern, we feel the Board's approach is the best practicable solution from the Federal Government's perspective.

Comment - In Section 3 of the Revised Statement the discussions of the diversion's environmental impacts are often not supported by quantitative data. This is particularly disturbing in the case of the Millers River project, it is estimated that as much as 55 and 74 percent of the Millers and the Tully Rivers' flows respectively may be diverted during an average year (Environmental Statement, pages 62 and 65.). The Environmental Statement asserts that "in no case would the flow in the river be reduced below the established rate necessary to protect the river environment" (pages 62, 65). The absence of information to confirm this should be corrected.

Response - The comment on the discussion within the revised draft

best copy available

Environmental Statement is well taken. As the SENE Study, the Connecticut River Supplemental Study have found, impact assessment in many ways is a subjective procedure and one in which exact quantification is not always possible. It is believed that the data available does allow a decision regarding the impacts on the river environment.

STATEMENT OF FINDINGS

NORTHFIELD MOUNTAIN WATER SUPPLY PROJECT

1. I have reviewed and evaluated, in the best over-all public interest, the documents concerning the Northfield Mountain Water Supply Project, as well as the stated views of other interested agencies and the concerned public, relative to the various practical alternatives available to meet the short range water supply needs of eastern Massachusetts, recognizing the regional objectives set forth in P. L. 89-298, Title I - Northeastern United States Water Supply Study.

2. The possible consequences of these alternatives have been studied according to engineering feasibility, environmental, social well-being and economic effects, including regional and national development goals.

3. In evaluation, the following points were considered pertinent:

A. Environmental Considerations - From an environmental standpoint, I have selected the optimum plan which will afford more enhancement than adverse effects. The recommended project will have beneficial effects on water supply, water quality and aesthetics. From the outset, this study made a determined effort to evaluate the impact which the project might have on environmental quality. An analysis was made regarding possible impacts on the Connecticut River estuary, the Connecticut River, and the receiving water storage reservoir. In general, impact caused by the diversion on the estuary and Connecticut River itself is expected to be minimal. The primary reason for this lack of environmental impact is the timing of diversions during high flow periods and the relatively small amount of water, when compared to river flow, which would be diverted.

In evaluating environmental impact on Quabbin and Wachusett Reservoirs, field and laboratory data included about 100 parameters, including chemical, physical, biological and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information and pollution abatement plans were considered and evaluated.

Within the receiving water body at Quabbin, the diverted flow may have impacts, but these possible impacts depend to a large degree on what engineering steps are taken prior to the actual diversion. For

example, the present waste loads in the river may provide opportunities for algae growth or oxygen depletion. But when current pollution abatement schedules are followed as required by the Water Quality Act of 1972, present loadings in the river will be reduced; and as a consequence, the probability of possible damage to Quabbin also minimized.

If no additional water is made available to the reservoir, then increased demands will deplete available storage. Declining storage volumes in turn will cause an overall loss in water quality. In addition to this, possible reservoir water quality deterioration caused by reduced storage levels and supply shortages in the receiver area could also cause a loss in environmental quality for those communities served by the system.

Finally, if the project was implemented, the additional water supplied would cause a corresponding increase in waste water discharge. However, the Water Quality Act of 1972 calls for full treatment of waste discharges by the early 1980's, thus, minimal impact can be expected.

B. Social Well-Being Considerations - I find that the overriding social well-being consideration in the study area is the reduction of the water supply shortage hazard which could cause damages and curtail normal development in communities to be serviced. The recommended project will provide a high degree of reliability for meeting future supply needs. Since the project under consideration involved transfer of a resource through inter-basin diversion, impacts were investigated for both source and receiver areas.

In general, tangible impacts felt by source areas will be related principally to limited land taking and subsequent construction activity of short term duration. Apart from the few physical structures proposed, the natural character of the area will remain unchanged. The bulk of surface work will come in remote wooded areas with a minimum of disruption to local traffic patterns. Evidence of the tunneling to Quabbin will be seen primarily as access shafts in three or four locations.

Apart from relatively small economic impacts, social impacts relating to supplier area residents' perception of equity are particularly significant and every effort was made to include these feelings in the plan formulation.

On the other hand, development of the recommended project would insure protection from water shortages and associated social and economic losses in the receiver communities. If the project was not implemented, social costs as well as economic costs could be expected.

C. Engineering Considerations - From an engineering standpoint, I have selected the project that would provide a high degree of protection and dependability against water supply shortages. Because the Connecticut River upstream from the intake is presently subjected to waste discharges, I find that implementation of the existing Federal - State abatement program should proceed as scheduled without delay.

The present "state-of-the-art" concerning potential benefits and possible shortcomings of water demand conservation measures was also investigated closely. I believe such measures have not advanced to the point where they can be relied upon as an alternative to the proposed structural measures. I do feel, however, that the potential of certain conservation techniques warrants further study as a management tool in assuring wise use of available resources. Concurrent investigations on water demand, its make-up and opportunities for conservation measures, therefore, are recommended as a parallel effort to the project. Other considered project alternatives did not meet the criteria and requirements for economic, social and environmental reasons.

D. Economic Considerations - From an economic standpoint, I have selected the economically optimum plan by providing a high degree of protection from water supply shortages and enhancement of social well-being and economic growth. The recommended project will have a net effect of increasing employment, tax revenues and property values and will preserve and stimulate further growth in the protected area.

4. I find that the proposed actions, as developed in the Recommendations, are based on thorough analysis and evaluation of various practicable alternative courses of action for achieving the stated objectives; that wherever adverse effects are found to be involved, they cannot be avoided by following reasonable alternative courses of action which would achieve the Congressionally specified purpose; that where the proposed action has an adverse effect, this effect is either ameliorated or substantially outweighed by other considerations

of national policy; that the recommended action is consonant with national policy, statutes and administrative directives; and that on balance the total public interest should best be served by implementation of the recommendations.

JOHN H. MASON
Colonel, Corps of Engineers
Division Engineer